

DESIGN AND CONSTRUCTION OF CIVIL, STRUCTURES AND TRACK WORKS, INVOLVING FORMATION IN EMBANKMENT /CUTTING, BALLAST ON FORMATION, TRACK WORKS, BRIDGES, STRUCTURES, BUILDINGS, YARDS & INTEGRATION WITH INDIAN RAILWAY'S EXISTING RAILWAY SYSTEM AND TESTING & COMMISSIONING ON DESIGN-BUILD LUMP SUM BASIS OF KHURJA-PILKHANI SECTION (APPROXIMATELY 222 ROUTE KM OF SINGLE LINE) OF EASTERN DEDICATED FREIGHT CORRIDOR

CIVIL, STRUCTURES AND TRACK WORKS

CONTRACT PACKAGE NO: 303

ICB No.: HQ/EN/EC/D-B/Khurja-Pilkhani Section
PART-4 - REFERENCE DOCUMENT
GEOTECH DATA - VOLUME 3
KHURJA TO PILKHANI

From Km. 1367.0 (ALJN-GZB) to Km 187.5 (SRE-UMB)

GEO TECH DATA

(PARALLEL SECTIONS)

PART. 1/3

EMPLOYER: DEDICATED FREIGHT CORRIDOR CORPORATION OF INDIA LTD
(A GOVERNMENT OF INDIA ENTERPRISE)
MINISTRY OF RAILWAYS

COUNTRY: INDIA

			CHANI SECTION CH DATA		
Sr. No.	Bridge No	DFCC Chainage	IR Km	Pag	e No.
				From	То
1	Introduction			1	5
	•	Khurja - Haf	izpur Section	1	•
2	3	-0.084	3.116	6	13
3	4	3813	3.813	14	21
5	5	3938 4366	3.938 4.366	22 30	29 37
6	6 7	5513	5.513	38	45
7	11	6950	6.950	46	55
8	12	7072	7.072	56	64
9	22	11588	11.588	65	72
10 11	23 29	12292 13416	12.292 13.416	73 81	80 88
12	32	14508	14.508	89	97
13	32A	14508	14.508	98	107
14	35	15305	15.305	108	115
15	36	16237	16.237	116	123
16 17	39 85	17170 33710	17.170 33.710	124 133	132 142
18	86	34403	34.403	143	150
19	112	46118	46.118	151	158
20	-	8000	8	159	167
21	-	9000	9	168	175
22	-	10000 18000	10 18	176 185	184 193
24	-	19260	19/4	194	202
25	-	20325	20/5	203	210
26	-	21260	21/3-21/4	211	219
27	-	22325	22/5	220	227
28 29	-	23065 24000	23/1 24	228 237	236 244
30	-	25000	25	245	254
31	-	26195	26/3	255	262
32	-	27260	27/4 - 27/3	263	270
33 34	-	28000 28910	28 28/14	271 279	278 287
35	-	30000	30	288	296
36	-	31000	31	297	304
37	-	32000	32	305	312
38	-	33715	33/10-11	313	322
39 40	-	35195 36000	35/3 36	323 331	330 338
41	-	37000	37	339	346
42	-	38000	38	347	354
43	-	39000	39	355	362
			ranpur Section		
44	-	85000	85	363	370
45 46	-	86000 89000	86 89	371 380	379 387
47	-	90000	90	388	395
48	-	91000	91	396	403
49	-	92000	92	404	413
50	-	93000	93	414	421
51 52	-	94000 98000	94 98	422 430	429 438
53	-	99000	99	439	436
54	-	100000	100	448	456
55	-	101000	101	457	464
56	-	102000	102	465	473
57 58	-	103000 104000	103 104	474 482	481 489
59	-	105000	105	490	497

60	-	106000	106	498	505
61	-	108000	108	506	513
62	-	109000	109	514	521
63	-	110000	110	522	530
64	-	112000	112	531	539
•		Talheri - F	Pilkhani Section		
65	-	83720	155	540	547
66	-	84720	156	548	556
67	203	85067.664	156/3-4	557	559
68	-	86067.664	157/3-4	560	562
69	204	86683.46	157/9-158/0	563	565
70	-	87528.46	158/12-13	566	568
71	205	87857.348	159/0-1	569	571
72	-	88767.348	159/14-15	572	574
73	206	89709.387	160/13-14	575	577
74	-	90634.406	161/13-14	578	580
75	207	91634.406	162/13-14	581	582
76	-	92634.406	163/13-14	583	585
77	-	93634.406	164/13-14	586	588
78	-	94634.406	165/13-14	589	591
79	-	95634.406	166/13-14	592	594
80	208	96750.679	167/10-11	595	596
81		97750.679	168/10-11	597	599
82	-	103236.851	174/450	600	609
83	-	106095	177/02-03	610	621
84	-	109750	180/15-17	622	630
85	-	110750	181/15-17	631	639
86	-	114896	186/00-01	640	651
87	4	102200	173/400	652	668
88	210	101275	172/03-04	670	687
89	219	108719	179/31-37	688	706
90	227	113415	184/15-17	707	725
91	211	101774	172/900 - 173/000	726	734
92	214	104339	175/500-600	736	744
93	215	105043	176/200-300	745	753
94	216	107071	178/02-03	754	762
95	217	107915	178/30-32	763	771
96	218	108073	179/11-13	772	780
97	221	110842	182/00-01	781	789
98	223	111800	182/27-29	790	798
99	226	112886	183/27-29	799	812
100	227A	113548	184/19-21	813	823
101	228	114219	185/05-07	824	836
102	231	115538	186/17-19	837	847
1	*		urja RFO		
103	-	-1600	-	848	855
104	-	-2356	-	856	863

INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC and the responsibility for carrying out the above is entrusted to M/s. Monarch Surveys, Pune.

This report includes field and Laboratory test results for the borehole location in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.

1.1 Scope of Work

1.1.1 Field Work

- ❖ Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- ❖ Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.
- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.

- ❖ Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

- (a) Visual and Engineering Classification
- (b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis
 - (i) Hydrometer Analysis/ Wet Sieve Analysis
- (c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils
- (d) Specific Gravity
- (e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO₄ contents.
- (f) Swelling Pressure Tests & Free Swelling Index
- (g) Bulk Density and Moisture Content
- (h) Unconfined Compression Tests on Clay Soils
- (i) Box Shear Test in case of sand
- (j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

(k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- Contents
- Introduction
- Investigation Methodology & Test Results
- Tables & Figures
- Subsurface Stratification

- Foundation System
- Recommendations

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to 12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-incharge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 Laboratory Testing: Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size Analysis Tests

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. These results are presented in Table 2.1.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. These tests are conducted as per I.S: 2720 (Part-4)-1985 and the test results are presented in table 2.1.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. The tests are conducted on such soil samples and the test results are presented in table 2.1.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

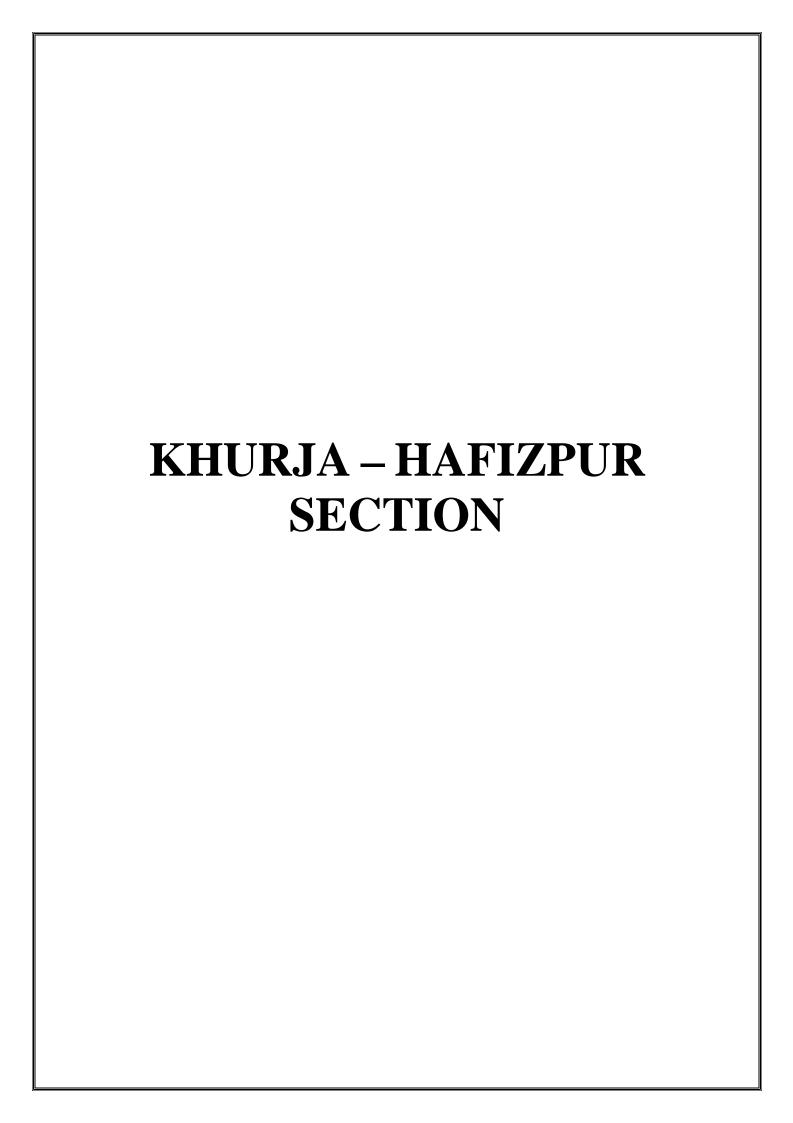
These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. The tests are conducted on the undisturbed soil samples and the test results are presented in Table 2.1.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.



Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC. Started On: 24/04/2008; Ended On: 25/04/2008 G.W.T: 11_50m

ာ	tarte	u O	II . 24/C	14/2008; Ended On: 25/	04/200	70	U.1	۷.I:											
					SP'	Τ - D	etail	S	rapl	nical	Re	pre	eser	ıtati	ion	ofS	P	y	
									##	10	20	3(4	4(5	5(6(7(8191	0	suc	
Denth of Ton of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					1.50	3	4	8	12	9								Loose	SS
				Brownish	3.00	UDS	Colle	cted										Loose	SS
				Loose Sandy Clayey Silt	4.50	3	4	7	11	d								Loose	SS
					6.00	4	6	9	15									Loose	SS
					7.50	4	8	7	15	C								Loose	SS
					9.00	4	5	9	14	q								Loose	SS
1	0.50			Greyish	10.50	5	6	11	17									M.Dense	SS
G	.w.T	¥		Medium Dense							\								
	2.00	-		Silty Clayey Fine Sand	12.00	8	9	16	25		1							M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.03 Location**

			BRIDGE N	0. 3 A	ΤI	RI	KM	3.1	16 (KH	UR	JA	- H	AFIZP	UR	SE	CT	ION	<u>V)</u>								
	Tab	le 2.1:	Laboratory '	Test R	esu	lts	on t	the	Soil	San	npl	es (Coll	ected fr	om	Br	idge	e No	0.03	Lo	catio	on					
pu						C	lay									Sie	ve A	nal	ysis			axial est	Be She	ox ear	(kPa)		
R.L of Sample below Existing Groun level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	$Consistency, I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
																											i
E.G.L-10.50	13	SS	Sandy Clayey Silt	13	-	-	-	-	2.67	0.3	15	1	-	Loose	0	0	0	25	60	15	-	-	18.9	30.3	-	-	SM
10.50-12.00	17	SS	Silty Sand	8	-	_	-	-	2.66	0.2	18	-	-	M.Dense	0	0	0	89	11	0	-	-	-	-	-	-	SM

11	Chemical Analy nple collected fr No.0	om Boı		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.89	88.34	79.56

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

k Layer-1 (from E.G.L to 10.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Sandy Clayey Silt

Brownish

10.50m

SPT of the layer

13

Loose

30.90°

* Layer-2 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 17

Relative Density Medium Dense

Angle of Shearing Resistance 32.10°

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	13	45
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of sandy clayey silt
 and can be considered as bearing strata for the proposed impending loads from
 the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 3 AT IR KM 3.116 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 11

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.30 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c=\ N\!/A$

 $N_q = 19.29$

 $N_{\gamma} = 23.94$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\nu} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 340.59 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 136.24 kPa

Limited to an allowable bearing pressure per running meter width: 130.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 130kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 130kPa and SPT of 11 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 25/04/2008; Ended On: 25/04/2008 G.W.T: 10.00m

				·	SP	T - D	etails	S	G	raph	ical	Re	pre	sent	tatio	n (of S	PT			
									0	10	0 2	030	0 4	0 50	060	7	0 80	0 90)	cy	
Depth of Top of	Lay er(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value											Relative Density/Consistency	Type of Sample
					1.50	2	3	4	7	١										Loose	SS
	•			Brownish Loose Sandy Clayey Silt	3.00	4	4	5	9											Loose	SS
				Santy Clayey Sin	4.50	UDS	Co llecte	ed												Loose	SS
					6.00	4	6	9	15		\									Loose	SS
7.	50		Ш		7.50	5	11	12	23)	Ì								M.Den se	SS
				Greyish	9.00	6	11	12	23		(\								M.Den se	SS
G.	V.T	▼ _		Medium Dense Silty Clayey Fine Sand	10.50	7	12	15	27											M.Den se	SS
12	.00				12.00	8	13	16	29											M.Den se	ss

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Bridge No.04 Location

		Tal	ole 2.1: Labora	tory 7	Test Result	s or	1 the	e So	il Sa	mp	les	Coll	ect	ed from	Br	idg	e No	0.04	Lo	cati	on						
75					Cl	lay										Sie	eve A	nal	ysis			axial est		ox ear	(kPa)		
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L-7.50	10	SS	Sandy Clayey Silt	13	-	-	-	-	2.67	0.3	15	-	-	Loose	0	0	0	23	60	17	-	-	18.6	29.6	-	-	SM
7.50.12.00	24	e e		6					2.66	0.2	10			M Damas				0.1	10	0							CM
7.50-12.00	24	SS	Silty Sand	6	-	-	-	-	2.66	0.2	18	-	-	M.Dense	U	0	0	81	19	0	-	-	-	-	-	-	SM

		analysis Results ed from Bore I No.04		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.88	94.67	77.86

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Sandy Clayey Silt

Brownish

7.50m

10

Loose

30.10°

* Layer-2 (from 7.50m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 4.50m
SPT of the layer 24

Relative Density Medium Dense

Angle of Shearing Resistance 34.20°

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the third week of May 2008.

BRIDGE NO. 4 AT IR KM 3.813

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

BRIDGE NO. 4 AT IR KM 3.813

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	10	45
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of sandy clayey silt
 and can be considered as bearing strata for the proposed impending loads from
 the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 4 AT IR KM 3.813 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

m

Least SPT-value of the Bearing Strata: 7

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 29.40 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 17.47$

 $N_{v} = 21.02$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 305.94 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 122.38 kPa

Limited to an allowable bearing pressure per running meter width: 100.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 100kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 100kPa and SPT of 07 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 25/04/2008; Ended On: 27/04/2008 G.W.T: 11.50m

				7/2000, Ended On . 27/0		T - D		s		phical Representation of SPT		
									0	10 2030 40 5060 70 8090	ıcy	
Depth of Top of	Lay er(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Den sity/Con sistency	Type of Sample
2.	50			Brownish Medium Dense Sandy Clayey Silt	1.50	6	10	11	21]	M.Den se	SS
					3.00	UDS	Co llecte	ed			Loose	SS
				Brownish Loose Sandy Clayey Silt	4.50	6	7	8	15		Loose	SS
6.	00				6.00	5	7	9	16		M.Den se	SS
				01	7.50	6	8	8	16		M.Den se	SS
				Greyish Medium Dense	9.00	7	7	10	17		M.Den se	SS
G.	W.T	↓		Silty Clayey Fine Sand	10.50	8	9	12	21		M.Den se	SS
12	.00	H	11		12.00	9	10	16	26	,	M.Den se	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level
Fig. 2.1 Soil Profile at Bridge No.05 Location

		Table	2.1: Laborator	y Test	Re	esul	ts o	n tl	ne So	oil S	am	ples	Co	llected	fro	m B	Brid	ge l	No.()5 L	ocat	tion					
рı						C	lay									Sie	eve A	nal	ysis			axial est		ox ear	(kPa)		
R.L of Sample below Existing Groun level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
F.G.L. 2.50	21	aa	G 1 GL GT	-					2.55	0.0	1.5			115			0	27	1	10			167	22.7			CD f
E.G.L-2.50	21	SS	Sandy Clayey Silt	9	-	-	-	-	2.66	0.2	17	-	-	M.Dense	0	0	0	27	61	12	-	-	16.7	32.7	-	-	SM
2.50-6.00	15	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	0.3	15	-	-	Loose	0	0	0	21	65	14	-	-	-	-	-	-	SM
6.00-12.00	18	SS	Silty Clayey Sand	8	-	-	-	-	2.66	0.2	17	-	-	M.Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.05											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)							
BH-01	12.00	7.78	180.43	135.24							

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

k Layer-1 (from E.G.L to 2.50m depth below)

Type of Strata Sandy Clayey Silt
Colour Brownish
Thickness of Layer 2.50m
SPT of the layer 21

Relative Density Medium Dense

Angle of Shearing Resistance 33.30°

* Layer-2 (from 2.50m to 6.00m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 3.50m
SPT of the layer 15
Relative Density Loose
Angle of Shearing Resistance 31.50°

* Layer-3 (from 6.00m to 12.00m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Greyish
Thickness of Layer 6.00m
SPT of the layer 18

Relative Density Medium Dense

Angle of Shearing Resistance 32.40°

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the fourth week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	25	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 5 AT IR KM 3.938 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

m

kPa

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 21

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 33.30 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 14.00

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 28.23$

 $N_{\gamma} = 39.32$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{\gamma} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 680.95 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 272.38 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 21 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 28/04/2008; Ended On: 29/04/2008 G.W.T: 11.50m

Stai	ici	ı O.	II . 20/C	14/2008; Ended On: 29/					11.5									
					SPT - Details raphical Representation of SP											>		
					## 10 21 3(4(51 6(7(81 90												oue	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
0.5	0			Filled Up Soil														
					1.50	4	4	5	9	q							M.Dense	SS
		Ì			3.00	UDS	Colle	cted									Loose	SS
				Brownish Loose Sandy Clayey Silt	4.50	4	5	5	10	0							Loose	SS
					6.00	4	6	5	11	đ							Loose	SS
8.5	0				7.50	5	7	7	14	,	1						Loose	SS
6.3	U				9.00	7	11	12	23		}						M.Dense	SS
G.W	т	+		Greyish Medium Dense Silty Clayey Fine Sand	10.50	6	9	10	19		d						M.Dense	SS
12.0		y			12.00	7	11	12	23		ſ						M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.06 Location**

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No.06 Location																											
ıd						C	lay									Sieve Analysis Triaxial Box Shear											
R.L of Sample below Existing Groun level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-0.50	_	DS	Filled Up Soil	_				_	_	_				_	_					_	_		_	_		_	
E.G.L-0.30	-	DS	Tilled Op Soll	-	┢▔	_	┢	_		_	Ē		-	-	_	_	┢	<u> </u>	_	_	_	-		-	<u>-</u>		-
0.50-7.50	10	SS	Sandy Clayey Silt	12	-	-	-	-	2.67	0.3	15	-	-	Loose	0	0	0	20	64	16	-	-	19.6	29.7	-	-	SM
7.50.12.00	24	aa							2.55	0.2	1.7							70									G) f
7.50-12.00	24	SS	Silty Clayey Sand	8	-	-	-	-	2.66	0.2	17	-	-	M.Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.06											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)							
BH-01	12.00	7.91	77.86	80.98							

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 0.50m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 0.50m

* Layer-2 (from 0.50m to 8.50m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 8.00m
SPT of the layer 11
Relative Density Loose
Angle of Shearing Resistance 30.30°

* Layer-3 (from 8.50m to 12.00m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Greyish
Thickness of Layer 3.50m
SPT of the layer 21

Relative Density Medium Dense

Angle of Shearing Resistance 33.30°

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the final week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	12	47
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of sandy clayey silt
 and can be considered as bearing strata for the proposed impending loads from
 the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 6 AT IR KM 4.366 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 9

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 29.80 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 18.09$

 $N_{v} = 21.94$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 317.45 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 126.98 kPa

Limited to an allowable bearing pressure per running meter width: 120.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 09 are computed to be in the order of 47mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 30/04/2008; Ended On: 01/05/2008 G.W.T: 9.50m

Starte	ea O	11:30/0	04/2008; Ended On: 01/	03/200	70	U.1	W . I :	9.50	m								
				SP'	Γ - D	etail	S	rapl	nical l	Rep	ores	sen	tati	on o	ofSP	ý	
								##	10	203	3(4	.(5	(6(7(8	3190	enc	
Depth of Top of Laver(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
0.30			Filled Up Soil														
		,	Brownish Loose	1.50	4	4	5	9	9							Loose	SS
			Sandy Clayey Silt	3.00	UDS	Colle	cted			١						Loose	ss
4.50				4.50	4	9	11	20	(1						M.Dense	SS
				6.00	5	10	12	22		0						M.Dense	SS
			Greyish Medium Dense	7.50	6	10	13	23		d						M.Dense	SS
G.W.T	<u> </u>		Silty Clayey Fine Sand	9.00	6	10	16	26		d						M.Dense	SS
				10.50	8	11	16	27		q						M.Dense	SS
12.00				12.00	9	12	18	30								M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.07 Location**

		, .	Гable 2.1: Laborat	tory Te	st Res	ults	on	the	Soi	l Sai	mpl	es (Coll	ected fi	rom	Br	idge	e No	.07	Lo	catio	n					
nd			Clay Sieve Analysis Test Box Shear																								
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	(%) TI	JT (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	с (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-0.30	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.30-4.50	9	SS	Sandy Clayey Silt	13	_	_	_	_	2.68	0.3	15	_		Loose	0	0	0	23	59	18	_	_	17.6	28.7		_	SM
0.30-4.30		55	Sandy Clayey Sin	13					2.00	0.5	1.5			Loose	- 0	0	- 0	23	3)	10			17.0	20.7			DIVI
4.50-12.00	24	SS	Silty Clayey Sand	7	-	-	-	-	2.66	0.2	17	-	-	M.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

	iter Sample	cal Analysis Result e collected from B Bridge No.07		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.88	100.94	112.12

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

Layer-1 (from E.G.L to 0.30m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 0.30m

* Layer-2 (from 0.30m to 4.50m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 4.20m
SPT of the layer 09
Relative Density Loose
Angle of Shearing Resistance 29.80°

* Layer-3 (from 4.50m to 12.00m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Greyish
Thickness of Layer 7.50m
SPT of the layer 24

Relative Density Medium Dense

Angle of Shearing Resistance 34.20°

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the final week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	12	47
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of sandy clayey silt
 and can be considered as bearing strata for the proposed impending loads from
 the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 7 AT IR KM 5.513 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 9

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 29.80 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 18.09$

 $N_{v} = 21.94$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 317.45 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 126.98 kPa

Limited to an allowable bearing pressure per running meter width: 120.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 09 are computed to be in the order of 47mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 08/05/2008; Ended On: 08/05/2008 G.W.T: 7.50m

Sta	rtec	a O	n : U8/0	05/2008; Ended On: 08/	05/200)8	G.1	<i>N</i> .T:	7.50	m									
					SP'	T - D	etail	S	rapl	nical	Re	pre	esei	ntat	ion	of	SP	×	
									##	10	121	3(4(:	5(6(7(819	90	suc	
Depth of Top of	Layer(m)	G.W.T.(m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
2.0	00			Filled Up Soil	1.50	SPT 1	Negle 	cted fo	or the	Fill L	ayer							-	DS
		•		Brownish Medium Dense Sandy Clayey Silt	3.00	6	9	15	24		٩	\						M.Dense	SS
4.5	50			Greyish Dense Silty Fine Sand	6.00	7	13	19	32				Þ					Dense Dense	ss ss
7.5	50	¥		,	7.50	8	11	17	28		(M.Dense	SS
9.5	50			Greyish Medium Dense Silty Fine Sand	9.00	6	12	16	28		(M.Dense	SS
				Greyish Very Dense	10.50	5	11	20	31									V.Dense	SS
12.	00			Silty Fine Sand	12.00	8	13	25	38			Ì	,					V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.11 Location**

		Table 2.	1: Laborator							_ `				ollected					No	. 11	Loc	atio	n				
pı				, 100			lay											nal			Tria	axial est	В	ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	Id	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
EGI 200		D.C.	E. 111 G																								
E.G.L-2.00	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.00-4.50	24	SS	Sandy Clayey Silt	9	-	-	-	1	2.7	-	17	-	-	M.Dense	0	0	0	21	54	25	-	-	16.7	33.2	-	-	SM
4.50-7.50	35	SS	Silty Sand	7	_	_	_	_	2.7	_	18	-	-	Dense	0	0	0	77	23	0	_	_	_	_	_	_	SM
			ziiiy build	,																							
7.50-9.00	28	SS	Silty Sand	9	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	83	17	0	-	-	-	-	-	-	SM
9.00-12.00	31	SS	Silty Sand	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM

	Sample o	-	Results cond rom Bore Ho	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm
BH-01	9.00	7.84	55.67	80.65

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 2.00m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 2.00m SPT of the layer -

* Layer-2 (from 2.00m to 4.50m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 2.50m
SPT of the layer 24

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.20 Deg.

* Layer-3 (from 4.50m to 7.50m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 3.00m
SPT of the layer 35
Relative Density Dense
Angle of Shearing Resistance, φ 37.375 Deg.

* Layer-4 (from 7.50m to 9.50m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 2.00m
SPT of the layer 28

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 35.40 Deg.

Layer-5 (from 9.50m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish 2.50m Thickness of Layer SPT of the layer 31 Relative Density Dense

Angle of Shearing Resistance, \$\phi\$ 36.275 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	24	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 11 AT IR KM 6.950 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column
Depth of foundation below the E.G.L: 3.50 m
Observed Maximum thickness of Filled up Soil: 2.00 m
Effective Depth of Foundation below E.G.L: 1.50 m
Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 24

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 34.20 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 30.92$

 $N_{v} = 43.93$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 608.70 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 243.48 kPa

Limited to an allowable bearing pressure per running meter width: 240.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 24 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 02/05/2008; Ended On: 02/05/2008 G.W.T: 4.50m

511	птс	u O	11.02/	05/2008; Ended On: 02/					4.50										
					SP'	Γ - D	etail	S	rapl	nical	Re	epr	ese	ntati	ion	of	SP	>	
									##	10	20	3(4(5(6(7(809	90	oue	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
0.	50			Filled Up Soil						-									
				Brownish	1.50	6	8	9	17		q							M.Dense	SS
	•	•		Medium Dense Sandy Silt	3.00	6	7	14	21		1	\						M.Dense	SS
4.	50	\			4.50	5	12	21	33			1	١					Dense	SS
				Brownish Dense Sandy Clayey Silt	6.00	9	18	23	41			/						Dense	SS
7.	50		Ш	Sandy Caryey Sin	7.50	7	8	14	22		1	′						M.Dense	SS
				Brownish to Greyish Medium Dense	9.00	9	10	16	26)						M.Dense	SS
				Sandy Clayey Silt	10.50	8	11	15	26		d							M.Dense	SS
12	.00				12.00	10	16	18	34			ſ						Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.12 Location**

BRIDGE NO. 12 AT IR KM 7.072 (KHURJA - HAFIZPUR SECTION)

		Table	e 2.1: Laborato	ry Te	st Re	sult	s oi	n th	e So	il Sa	ւույ	ples	Co	llected	froi	n B	rid	ge N	o. 1	12 L	ocat	ion					
pu						Cla	ay									Sie	eve A	naly	ysis			xial est	Box	Shear	(kPa)		
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, L	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%) Coarse (%) Medium (%) Fine (%) Silt (%)				Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification	
E.G.L-0.50	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.50-4.50	19	SS	Sandy Silt	11	-	-	-	-	2.68	-	16	-	-	M.Dense	0	0	0	44	56	0	-	-	14.5	31.5	-	-	SM
4.50-7.50	37	SS	Sandy Clayey Silt	14	27	16	11	1.2	2.65	_	18	_	_	Dense	0	0	0	15	60	25	-	_	22.4	36.9	_	_	SM
7.50	- 57	55	Sandy Shayey Bilt						2.03					Zense					- 50					23.7			5.11
7.50-12.00	25	SS	Sandy Clayey Silt	14	31	14	17	1.0	2.66	-	17	-	-	M.Dense	0	0	0	11	66	23	-	-	-	-	-	-	SM

conduct	ed on Wate	nical Analysis R r Sample collec at Bridge No. 12	ted fr	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.81	59.50	89.3

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 0.50m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 0.50m SPT of the layer -

* Layer-2 (from 0.50m to 4.50m depth below)

Type of Strata Sandy Silt
Colour Brownish
Thickness of Layer 4.00m
SPT of the layer 19

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 32.70 Deg.

* Laver-3 (from 4.50m to 7.50m depth below)

Type of Strata Sandy Clayey Silt Colour Brownish Thickness of Layer 3.00m SPT of the layer 37 Relative Density Dense Angle of Shearing Resistance, ϕ 37.925 Deg.

* Layer-4 (from 7.50m to 12.00m depth below)

Type of Strata Sandy Clayey Silt Colour Brownish to Greyish

Thickness of Layer 4.50m SPT of the layer 25

Relative Density Angle of Shearing Resistance, φ

The ground water table was encountered at a depth of 4.50m within the explored depth of investigation in the first week of May 2008.

Medium Dense

34.50 Deg.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	20	40
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 12 AT IR KM 7.072 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m
Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 17

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 32.10 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m³

Effective Overburden pressure at foundation level (q) 12.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 24.66$

 $N_{v} = 33.16$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 517.32 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 206.93 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 17 are computed to be in the order of 40mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 01/05/2008; Ended On: 02/05/2008 G.W.T: 11.50m

				237 2000; Ended On : 027	SPT - Details raphical Representation of SP							×						
						## 10 21 3(4(5) 6(7(8) 90								enc				
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
0.	25			Filled Up Soil						-	-	-	-	-	-			
					1.50	4	8	8	16	G							M.Dense	SS
	•	•			3.00	4	8	9	17	(M.Dense	SS
				Brownish Medium Dense Sandy Clayey Silt	4.50	5	8	9	17	(M.Dense	SS
					6.00	5	8	11	19		d						M.Dense	SS
					7.50	6	9	12	21		O						M.Dense	SS
					9.00	8	10	13	23		\(\					M.Dense	SS
10	.50				10.50	9	12	24	36			}					Dense	SS
	X 7 (B)	¥		Greyish														
	V.T .00	V		Dense	12.00	10	14	25	39								Dense	SS
12	.00	11		Silty Clayey Fine Sand	12.00	10	14	43	33			(•				Delise	သပ

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.22 Location**

BRIDGE NO. 22 AT IR KM 11.588 (KHURJA - HAFIZPUR SECTION)

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 22 Location																										
q						Cla	y								Sieve Analysis					est		Box Shear					
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	(%) TI	PL (%)	Id	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-0.25		DC	E31.4 II. C.3																								
E.G.L-0.25	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.25-10.50	19	SS	Sandy Clayey Silt	10	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	25	51	24	-	-	18.7	31.6	-	-	SM
10.50-12.00	36	SS	Silty Sand	7	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	_	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 22											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)							
BH-01	12.00	7.79	119.77	157.46							

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 0.25m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 0.25m SPT of the layer -

* Layer-2 (from 0.25m to 10.50m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 10.25m
SPT of the layer 19

Relative Density Medium Dense Angle of Shearing Resistance, φ 32.70 Deg.

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata
Colour
Greyish
Thickness of Layer
SPT of the layer
Relative Density
Silty Fine Sand
Greyish
1.50m
36
Dense

Angle of Shearing Resistance, ϕ 37.65 Deg.

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 1.75m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.75m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.75	18	36
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 22 AT IR KM 11.588 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.25 m

Effective Depth of Foundation below E.G.L: 1.75 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 16

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 31.80 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 23.76$

 $N_{v} = 31.63$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 450.89 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 180.35 kPa

Limited to an allowable bearing pressure per running meter width: 180.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 180kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 180kPa and SPT of 16 are computed to be in the order of 36mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 02/05/2008; Ended On: 03/05/2008 G.W.T: 11.50m

Dia	1100	4 0	11.02/	75/2008, Elided Oll . 05/					11.5					_			1	
					SP'	Γ - D	etail	S	rapl	nical	Re	pre	sen	tati	on	ofSl	2 5	
									##	10	20	3(4	1(5	(6(7(8	8190	e e e	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
					1.50	4	6	7	13	q							Loose	SS
				Brownish Loose	3.00	UDS	Colle	cted									Loose	SS
				Sandy Clayey Silt	4.50	4	6	7	13	q							Loose	SS
6.0	00		H		6.00	5	7	9	16	C							M.Dense	s
				Brownish	7.50	6	8	11	19								M.Dense	ss ss
				Medium Dense Silty Clayey Fine Sand	9.00	7	10	16	26		1	\					M.Dense	ss
10.	50		Ш		10.50	10	21	26	47			\	7				Dense	ss
		Ш		Greyish									1					
	V.T	V		Dense	12.00	1.0		27	40				1				Dense	ac
12.	UU			Silty Clayey Fine Sand	12.00	10	22	27	49				ď				Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.23 Location**

		Table 2.1: L	aboratory T	est R	esu	ılts	on	the	Soil	Sar	npl	es C	oll	ected f	rom	ı Br	idg	e N	0. 2	3 L	ocat	ion					
g						C	lay									Sie	ve A	nal	ysis			axial est	Be She	ox ear	Cu (kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L-6.00	13	DS	Sandy Clayey Silt	14	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	22	56	22	-	-	17.8	30.1	-	-	SM
6.00-10.50	20	SS	Silty Clayey Sand	10	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	85	9	6	-	-	-	-	-	-	SM
10.50-12.00	47	SS	Silty Clayey Sand	6	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	78	14	8	-	-	-	-	-	-	SM

Table 2.2: Cl Water Samp	ole collect	nalysis Resul ed from Bore No. 23		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.8	116.50	145.4

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata

Colour

Brownish

Coloum

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

6.00m

13

Loose

30.90 Deg.

* Layer-2 (from 6.00m to 10.50m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Brownish
Thickness of Layer 4.50m
SPT of the layer 20

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.00 Deg.

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 47

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 40.325 Deg.

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	15	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 23 AT IR KM 12.292 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 13

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.90 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 21.08$

 $N_{v} = 27.01$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 375.37 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 150.15 kPa

Limited to an allowable bearing pressure per running meter width: 150.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 04/05/2008; Ended On: 05/05/2008 G.W.T: 10.50m

				7572000, Ended On : 057			etail		rapl		Re	pre	sen	ıtati	on	ofS	P	>	
									##	10	20	3(4	1(5	6(6(7(8	319	0	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
				Brownish Loose Sandy Clayey Silt	1.50	4	6	9	15	9		-	•		•	-		Loose	SS
4	.50			Saley easys, sale	3.00 4.50	UDS 4	Colle	cted	18									Loose M.Dense	SS SS
	.50				6.00	5	7	12	19		o							M.Dense	SS
				Brownish Medium Dense Silty Clayey Fine Sand	7.50	4	8	12	20		d							M.Dense	SS
					9.00	5	9	14	23		1	\						M.Dense	SS
10	.50	↓	H	Greyish	10.50	6	15	18	33									Dense	SS
12	2.00			Dense Silty Clayey Fine Sand	12.00	7	15	19	34									Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.29 Location**

		Table	2.1: Laborat	ory T	est	Res	sults	on	the S	Soil	San	nple	s C	ollected	fro	m F	Brid	ge N	No. 2	29 L	ocat	ion					
pu						C	lay									Sie	eve A	naly	ysis			axial est	Be She		(kPa)		
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	$c (kN/m^2)$	φ (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-4.50	15	DS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	26	54	20	-	-	19.7	30.9	-	-	SM
4.50-10.50	20	SS	Silty Clayey Sand	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	78	15	7	-	-	-	-	-	-	SM
10.50-12.00	33	SS	Silty Clayey Sand	8	-	-	-	-	2.65	-	18	-	-	Dense	0	0	0	76	16	8	-	-	-	-	-	-	SM

	ample coll	•	Results condu com Bore Hol	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hď	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.78	155.46	124.68

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

4.50m

15

Loose

31.50 Deg.

* Layer-2 (from 4.50m to 10.50m depth below)

Type of Strata Silty Clayey Fine Sand

ColourBrownishThickness of Layer6.00mSPT of the layer20

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.00 Deg.

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 33

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 36.825 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	16	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 29 AT IR KM 13.416 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 15

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 31.50 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 22.87$

 $N_{v} = 30.09$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 410.14 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 164.06 kPa

Limited to an allowable bearing pressure per running meter width: 160.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 15 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC. Started On: 05/05/2008; Ended On: 07/05/2008 G.W.T: 10.50m

				,	SP'	T - D	etail	S	rapl	nical	Re	pre	sen	tati	on	of	SP	y	
									##	10	20	3(4	4(5	16(7(80	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					1.50	4	5	5	10	q								Loose	ss
	•	•		Brownish Loose	3.00	UDS	Colle	cted										Loose	SS
			Ш	Sandy Clayey Silt	4.50	4	5	9	14	o								Loose	SS
			Ш		6.00	4	5	10	15	o								Loose	SS
7.	50		Ш		7.50	6	7	10	17	d								M.Dense	SS
					9.00	6	8	12	20		\							M.Dense	SS
G.V	V.T	<u>\</u>			10.50	8	12	17	29		\	}						M.Dense	ss
				Brownish	12.00	8	12	13	25		d							M.Dense	SS
				Medium Dense Silty Clayey Fine Sand	13.50	DS C	ollect	ed										M.Dense	DS
					15.00	9	13	15	28		¢	ļ						M.Dense	ss
			Ш		16.50	9	14	14	28		¢)						M.Dense	SS
					18.00	10	14	16	30									M.Dense	SS

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At Bridge No. 32

Started On: 05/05/2008; Ended On: 07/05/2008 G.W.T: 10.50m

שני	ai tC	u ()	11.05/	13/2008; Elided Oll: 07	7				10.5			
					SP'	Τ - D	etail	S	raph	nical Representation of SP	21	
J									##	10 21 3(4(5) 6(7(8) 90	iter	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistenc y	Type of Sample
		 			19.50	9	15	16	31	9	Dense	SS
		 			21.00	16	16	17	33	0	Dense	SS
		 		Greyish Dense	22.50	10	17	17	34	d	Dense	SS
				Silty Fine Sand	24.00	11	19	19	38	d	Dense	SS
					25.50	12	20	21	41		Dense	SS
					27.00	12	22	23	45		Dense	SS
		 			28.50	13	22	25	47	d	Dense	SS
30	.00	 			30.00	14	24	26	50		Dense	SS

Bore Hole Terminated at a depth of 30.00m below the existing ground level Fig. 2.1 Soil Profile at Bridge No.32 Location

		Table	2.1: Laborato	ry Te	est l	Res	ults	on	the	Soil	Sai	nple	es C	Collecte	d fr	om	Bri	dge	No.	. 32	Loca	ation	l				
þm						C	lay									Sie	ve A	naly	ysis			est	She	ox ear	ı (kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	Id	Consistency, ${ m I_C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-7.50	13	SS	Sandy Clayey Silt	13	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	21	57	22	14.8	30.1	-	-	-	-	SM
·																											
7.50-30.00	32	SS	Silty Clayey Sand	9	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	79	15	6	-	-	-	-	-	-	SM

Table 2.2: Che on Water San	nple coll	•	rom Bore Ho	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.88	75.43	80.44

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

7.50m

13

Loose

30.90 Deg.

* Layer-2 (from 7.50m to 30.00m depth below)

Type of Strata Silty Clayey Fine Sand

ColourBrownishThickness of Layer22.50mSPT of the layer32Relative DensityDenseAngle of Shearing Resistance, ϕ 36.55 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level.

Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No.	Diameter of	Safe Load	Safe Pull Out	Safe Lateral
	Pile	Carrying	carrying	Load
	(mm)	Capacity	Capacity	carrying
		(kN)	(kN)	Capacity
				(kN)
1	1000	10000	5922	600

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- **3.** The bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level. Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 32 AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION) DESIGN OF PILE FOUNDATION(Refer:BH-01)

Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile

Bored Cast in Situ

1.1 Geometrical Data

Assumed Diameter of pile(D):

Assumed R.L of E.G.L:

Length of pile below E.G.L.(l):

R.L. of Bot. of Pile

1000.0 mm

30.000 m

-30.000 m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1 Layer-I Type of Strata: Silty Sand Average SPT of the strata,N: 13	
Bulk Density of the strata,γ: 15	kN/m ³
Angle of Shearing Resistance, \$\phi\$: 30.9 Depth of top of Strata: 0.00	Deg. m
Depth of bottom of Strata: 7.50 Average Thickness of Strata, I _c : 7.50	m m
Effective overburden pressure over the top of strata, σ_{top} : 0.00	kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom} : 37.50	kN/m ²
Effective overburden pressure at the middle of the strata, σ_{middle} : 18.75 Coeff. Of Earth Pressure, k: 1.00	kN/m ²
Skin Resistance of the pile, q_s : 264.40 $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$	kN

1.2.1.2 Layer-II

Type of Strata: Silty Clayey Fine Sand

Average SPT of the strata, N: 32

Bulk Density of the strata, γ : 19 kN/m³
Angle of Shearing Resistance, ϕ : 36.55 Deg.

Depth of top of Strata: 7.50 m

Depth of bottom of Strata: 30.00 m

Average Thickness of Strata, I_c : 22.50 m

Effective overburden pressure over the top of strata, σ_{top} : 37.50 kN/m² Effective overburden pressure over the bottom of strata, σ_{bottom} : 240.00 kN/m²

Effective overburden pressure at the middle of the strata, σ_{middle} : 138.75 kN/m²

Coeff. Of Earth Pressure,k: 2.00

Skin Resistance of the pile,q_s: 14541.1 kN

 $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$

Ultimate Skin Resistance, q_s: 14805.5 kN

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata Silty Sand

Cross-Sectional Area of pile, Ap: 0.785 m²

	R.L of bottom of pile: -30.00	
	Minimum SPT-value of the Bearing Strata 50	
	Angle of Shearing Resistance(ASR) 41.00	Degrees
	Bearing Capacity Factor(Nq) 150.00	
	Effecitve Over Burden Pressure at the bottom of pile (q) 100.00	kPa
	(limited to a maximum value produced by a soil layer of	
	thickness equal to 20 times the diameter of pile from the	
	N.G.L.)	
	Ultimate End Bearing Resistance (Qp) 11781.0	$\mathbf{k}\mathbf{N}$
	(Qp=Ap*q*Nq)	
1.3.0	Ultimate Load Carrying Capacity (Qu=Qp+q _p) 26586.5	kN
	Safe Load Carrying Capacity (Qsafe =Qu/2.5) 10634.6	kN
	However, limit Q_{safe} to the structural capacity of pile: 10000.0	kN

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at $\label{eq:Km156} Km156\ on\ Eastern\ Freight\ Corridor\ in\ line\ with\ Tender\ No.\ HQ/EN/Pre.\ (Works)/MTC.$ $\ Started\ On: 08/06/2008;\quad Ended\ On: 10/06/2008\quad G.W.T:\ 5.00m$

	artec		11 . 00/0	06/2008; Ended On: 10/		Γ - D			5.00 rapl		1 R <i>e</i>	enre	eser	ntati	on	οf	SP		
					- 51	1 - D	ctan		##		0 20	_				_	-	ıcy	
Ţ									##	ΙÌ	1	1	4(,	T	T	01	90	steı	0
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					1.50	5	5	7	12	(Ì	•						Loose	SS
	•	1	Н	Brownish Loose	3.00	UDS	Colle	cted										Loose	SS
G.	W.T	↓	Н	Sandy Clayey Silt	4.50	4	5	5	10	o								Loose	SS
		 	П		6.00	4	5	7	12	(Loose	SS
		 	Н		7.50	6	6	9	15									Loose	SS
9	.00		H		9.00	6	7	9	16		1							M.Dense	SS
		 			11.00	7	13	14	27)						M.Dense	SS
					12.50	7	9	12	21									M.Dense	SS
				Brownish	14.00	7	8	11	19									M.Dense	DS
				Medium Dense Silty Fine to Medium Coarse Sand	15.50	Distu	rbed i	Sampl	le Coll	lecte	d							M.Dense	SS
		 			17.00	8	11	12	23		9							M.Dense	SS
					18.50	9	12	14	26		d	\						M.Dense	SS
19	.00											1							

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At Bridge No. 32-A

Started On: 08/06/2008; Ended On: 10/06/2008 G.W.T: 5.00m

51	arı	ou O	11 . 00/(76/2008; Elided Oll : 10/					3.00											
					SP	Γ - D	etail	S	rapi	nical	Re	pre	ese	ntat	io	n o	fSP			
									##	10	20	3(4(516	(7	(8)	90		ten E	
Depth of Top of	Laver(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative	Density/Consistency	Type of Sample
					20.00	10	14	20	34			9						De	ense	SS
					22.00	10	14	21	35			\	١					De	ense	SS
				Greyish Dense	23.50	12	16	24	40			,						De	ense	SS
				Silty Fine Sand	25.00	12	18	29	47				}					De	ense	ss
					26.50	14	19	31	50				(\				De	ense	ss
28	3.00			0	28.00	15	21	34	55									V.I	Dense	ss
				Greyish																
30	0.00	<u> </u>		Dense Silty Fine Sand	29.50	15	27	28	55									V.I	Dense	SS

Bore Hole Terminated at a depth of 30.00m below the existing ground level Fig. 2.1 Soil Profile at Bridge No.32-A Location

BRIDGE NO. 32A AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 32A Location																											
pu							C	lay								Sieve Analysis						xial est		Box Shear				
R.L of Sample below Existing Ground level(m)		SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	Id	Consistency, $ m I_{c}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-9	0.00	12	SS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	18	60	22	14.3	29.8	-	-	-	-	SM
9.00-19	.00	22	SS	Silty Sand	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	17	66	17	0	-	-	-	-	-	-	SM
10.00.20	2.00	4.1	gg	G.1. G. 1	- 0					2.66		10				0	0	_	70	22	_							CNA
19.00-28	5.00	41	SS	Silty Sand	9	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
28.00-30	0.00	55	SS	Silty Sand	8	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	73	27	0	-	-	-	-	-	-	SM

	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 32A											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)								
BH-01	6.00	7.89	70.48	78.41								

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

9.00m

12

Loose

30.60 Deg.

* Layer-2 (from 9.00m to 19.00m depth below)

Type of Strata Silty Fine to Medium

Coarse Sand

Colour Brownish
Thickness of Layer 10.00m
SPT of the layer 22

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 33.60 Deg.

* Layer-3 (from 19.00m to 28.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish

Thickness of Layer 9.00m

SPT of the layer 41

Relative Density Dense

Angle of Shearing Resistance, φ 38.975 Deg.

* Layer-4 (from 28.00m to 30.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish

Thickness of Layer 2.00m SPT of the layer 55

Relative Density Very Dense Angle of Shearing Resistance, φ 41.75 Deg.

The ground water table was encountered at a depth of 5.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level.

Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No. Diameter of	Safe Load	Safe Pull Out	Safe Lateral
-------------------	-----------	---------------	--------------

	Pile	Carrying	carrying	Load
	(mm)	Capacity	Capacity	carrying
		(kN)	(kN)	Capacity
				(kN)
1	1000	10000	4611	600

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- **3.** The bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level. Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 32A AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION) **DESIGN OF PILE FOUNDATION(Refer:BH-01)**

Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile

Bored Cast in Situ

1.1 Geometrical Data

Assumed Diameter of pile(D): **1000.0** mm Assumed R.L of E.G.L: 0.000 m Length of pile below E.G.L.(1): **30.000** m R.L. of Bot. of Pile -30.00 m

1.2 Design of Pile for Vertical Compression

1.2.1	Computation of Skin Resistance:		
1.2.1.1	Type of Strata:	Sandy Clayey Si	lt
	Average SPT of the strata,N: Bulk Density of the strata, γ : Angle of Shearing Resistance, ϕ : Depth of top of Strata: Depth of bottom of Strata: Average Thickness of Strata, I_c : Effective overburden pressure over the top of strata, σ_{top} : Effective overburden pressure over the bottom of strata, σ_{bottom} : Effective overburden pressure at the middle of the strata, σ_{middle} : Coeff. Of Earth Pressure, k : Skin Resistance of the pile, q_s : $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$	15 30.6 0.00 7.50 7.50 0.00 37.50 18.75 1.00	kN/m ³ Deg. m m kN/m ² kN/m ² kN/m ²
1.2.1.2	Type of Strata: Average SPT of the strata,N: Bulk Density of the strata, γ : Angle of Shearing Resistance, ϕ : Depth of top of Strata: Depth of bottom of Strata: Depth of bottom of Strata: Average Thickness of Strata, I_c : Effective overburden pressure over the top of strata, σ_{top} : Effective overburden pressure over the bottom of strata, σ_{bottom} : Effective overburden pressure at the middle of the strata, σ_{middle} : Coeff. Of Earth Pressure, k : Skin Resistance of the pile, q_s : $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$	22 17 33.6 9.00 19.00 10.00 37.50 107.50 72.50 1.50	kN/m ³ Deg. m m m kN/m ² kN/m ²
1.2.1.3	Type of Strata: Average SPT of the strata,N:	41	3
	Bulk Density of the strata, γ :	19	kN/m^3

Bulk Density of the strata,γ: 19 Angle of Shearing Resistance,φ: 38.975

Deg.

	Depth of top of Strata:		m
	Depth of bottom of Strata:		m
	Average Thickness of Strata, I _c :		m
	Effective overburden pressure over the top of strata, σ_{top} :	107.50	kN/m ²
Effec	tive overburden pressure over the bottom of strata, σ_{bottom} :	188.50	kN/m^2
Effect	we overburden pressure at the middle of the strata, σ_{middle} :	148.00	kN/m^2
	Coeff. Of Earth Pressure,k:	2.00	
	Skin Resistance of the pile,q _s :	6771.2	kN
	$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$		
1.2.1.4	Layer-IV		
	Type of Strata:	Silty Sand	
	Average SPT of the strata,N:	55	
	Bulk Density of the strata, γ :	20	kN/m^3
	Angle of Shearing Resistance,φ:		Deg.
	Depth of top of Strata:		m
	Depth of bottom of Strata:		m
	Average Thickness of Strata, I _c :		m
	Effective overburden pressure over the top of strata, σ_{top} :	188.50	kN/m ²
Effec	tive overburden pressure over the bottom of strata, σ_{bottom} :	208.50	kN/m ²
Effect	ve overburden pressure at the middle of the strata, σ_{middle} :	198.50	kN/m^2
	Coeff. Of Earth Pressure,k:	2.00	
	Skin Resistance of the pile,q _s :	2226.4	kN
	$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$		
	Ultimate Skin Resistance,qs:	11528.7	kN
1.2.2 Comp	outation of End Bearing Resistance:		
	Type of Bearing Strata	Silty Sand	_
	Cross-Sectional Area of pile, Ap:		m^2
	R.L of bottom of pile:		
	Minimum SPT-value of the Bearing Strata		D
	Angle of Shearing Resistance(ASR) Bearing Capacity Factor(Nq)		Degrees
	Effective Over Burden Pressure at the bottom of pile (q)		kPa
	imited to a maximum value produced by a soil layer of	100.00	III W
(1	ickness equal to 20 times the diameter of pile from the		
	nemics equal to 20 times the diameter of phe from the		
	N.G.L.)		
	N.G.L.) Ultimate End Bearing Resistance (Qp)	15315.3	kN
	N.G.L.)	15315.3	kN
	N.G.L.) Ultimate End Bearing Resistance (Qp)		kN kN
tl	N.G.L.) Ultimate End Bearing Resistance (Qp) (Qp=Ap*q*Nq)	26844.0 10737.6	

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 08/05/2008; Ended On: 09/05/2008 G.W.T: 10.50m

1.50 3 4 7 111 q Loose SS Brownish Loose Sandy Clayey Silt 4.50 4 7 8 15 0 Loose SS 6.00 6.00 4 8 9 17 0 M.Dense SS M.Dense SS Silty Clayey Fine Sand 9.00 7 9 11 20 0 Greyish 10.50 11 17 23 40 0 Dense SS					7572000, Ended On : 077			etail		rapl		Re	pre	sen	itat	ior	ı of	SP	>	
1.50 3 4 7 111 q Loose SS Brownish Loose Sandy Clayey Silt 4.50 4 7 8 15 0 Loose SS 6.00 6.00 4 8 9 17 0 M.Dense SS M.Dense SS Silty Clayey Fine Sand 9.00 7 9 11 20 0 Greyish 10.50 11 17 23 40 0 Dense SS										##	10	20	3(4	4(5	516(7((8)	90	enc	
Brownish Loose Sandy Clayey Silt 4.50	Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile		Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consist	Type of Sample
Loose Sandy Clayey Silt 4.50						1.50	3	4	7	11	9								Loose	SS
6.00					Loose	3.00	UDS	Colle	cted										Loose	SS
7.50 5 8 8 16 Brownish Medium Dense Silty Clayey Fine Sand 9.00 7 9 11 20 M.Dense SS M.Dense SS M.Dense SS M.Dense SS Dense SS						4.50	4	7	8	15	o								Loose	SS
Brownish	6	.00				6.00	4	8	9	17	(M.Dense	SS
Silty Clayey Fine Sand 9.00 7 9 11 20 d M.Dense SS 10.50 10.50 11 17 23 40 Dense SS Greyish						7.50	5	8	8	16	(\ \							M.Dense	SS
Greyish						9.00	7	9	11	20		1	\						M.Dense	SS
	10).50	¥		Gravish	10.50	11	17	23	40			/	Ì					Dense	SS
					Dense	12.00		10	2.5										Domas	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.35 Location**

BRIDGE NO. 35 AT IR KM 15.305 (KHURJA - HAFIZPUR SECTION)

	Ta	able 2.1	1: Laboratory	y Tes	t R	esu	lts (on t	he S	oil S	San	nple	s C	ollected	d fro	om	Bri	dge	No	. 35	Loc	atio	n				
g.						C	lay									Sie	ve A	naly	sis			xial est		ox ear	(kPa)		
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
]	il I										_	_	9 2	1	<u> </u>	Ť	Н					-					
 													92				I										
E.G.L-6.00	13	DS	Sandy Clayey Silt	15	-	-	-	-	2.7	-	15	-	-	Loose	0	0		21		14		-	17.8	30.0	-	-	SM
E.G.L-6.00	13	DS	Sandy Clayey Silt	15	-	-	-	-		-			-					21		14		-	17.8	30.0	-	-	SM
E.G.L-6.00 6.00-10.50	13		Sandy Clayey Silt Silty Clayey Sand		-	1	-	-		-			-		0		0	21	65			-	17.8	30.0	-	-	SM SM
									2.7	-	15	-	-	Loose	0	0	0		65			-		30.0	-	-	
		SS		9					2.7	-	15	-	-	Loose	0	0	0		65	8		-		30.0	-	-	

conducted o		Sample	llysis Results e collected fr e No. 35	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.81	140.03	121.2

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata

Colour

Brownish

Coloum

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

6.00m

13

Loose

30.90 Deg.

* Layer-2 (from 6.00m to 10.50m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Brownish
Thickness of Layer 4.50m
SPT of the layer 18

Relative Density Medium Dense Angle of Shearing Resistance, φ 32.40 Deg.

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 40

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 38.75 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	12	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 35 AT IR KM 15.305 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 11

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.30 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 19.29$

 $N_{v} = 23.94$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma}=\ 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 340.59 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 136.24 kPa

Limited to an allowable bearing pressure per running meter width: 120.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 11 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 09/05/2008; Ended On: 10/05/2008 G.W.T: 10.50m

				Ended on : 10/			etail		rapl		Re	epre	eser	ıtati	on	ofS	SP	>	
									##	10	20	3(4(5	5(6(7(819	00	enc	
Depth of Top of	Layer(m)	G.W.T.(m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					1.50	3	5	5	10	G	-		-		-	-		Loose	SS
	•				3.00	UDS	Colle	cted										Loose	SS
				Brownish Loose Sandy Clayey Silt	4.50	4	5	7	12	q								Loose	SS
					6.00	5	7	7	14	0								Loose	SS
					7.50	5	7	8	15	đ								Loose	SS
9.	00				9.00	6	9	9	18	(M.Dense	ss
G.V	V.T	<u></u>		Greyish to Brownish Medium Dense	10.50	7	9	11	20									M.Dense	SS
12	.00			Silty Fine Sand	12.00	7	10	12	22									M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No. 36 Location**

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 36 Location Triaxial Bo														lected f	ron	ı Br	idg	e N	0.30	6 L	ocati	ion					
pu						C	lay									Sie	eve A	nal	ysis			axial est		ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, ${f L}_{ m c}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-9.00	13	DS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	23	68	9	-	-	16.8	30.0	-	-	SM
											<u> </u>		<u> </u>														
9.00-12.00	19	SS	Silty Sand	11	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM

Table 2.2: Che Water Sample	e collected	•		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.84	140.95	133.23

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

9.00m

13

Loose

30.90 Deg.

* Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 3.00m SPT of the layer 19

Relative Density Medium Dense Angle of Shearing Resistance, φ 32.70 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are loose deposits of coarse-grained type in the form of non-plastic sandy silt but can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	11	49
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are loose deposits of coarse-grained type in the form of sandy silt but can be considered as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 36 AT IR KM 16.237 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 2.00 m m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 10

Type of Shear Failure: General

Angle of Shearing Resistance, ϕ : 30.00 Deg.

1 Design Parameters:

kN/m³ Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 18.40$

 $N_{v} = 22.40$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 323.20 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 129.28 kPa

Limited to an allowable bearing pressure per running meter width: 110.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 110kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 110kPa and SPT of 10 are computed to be in the order of 49mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 11/05/2008; Ended On: 12/05/2008 G.W.T: 10.50m

St	arte	u O	n:11/(05/2008; Ended On: 12/	03/200	70	Ü.۱		10.5										
					SP'	T - D	etail	.s	rapl	nica	l R	.epi	rese	ntat	ion	of	SP	ý	
									##	10	0 2	(3)	(4(5161	7(809	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					1.50	3	4	6	10	9								Loose	SS
		^			3.00	UDS	Colle	cted										Loose	SS
				Brownish Loose Sandy Clayey Silt	4.50	4	5	7	12	0								Loose	SS
					6.00	4	5	8	13	q								Loose	SS
					7.50	5	7	8	15	(0							Loose	SS
9	.00		Ш		9.00	6	7	10	17		\							M.Dense	SS
G.	W.T	<u></u>		Greyish to Brownish Medium Dense	10.50	8	10	12	22									M.Dense	SS
12	2.00			Silty Fine Sand	12.00	10	13	13	26		ļ							M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No. 39 Location**

		Table 2	2.1: Laborato	ry Tes	t R	esu	lts c	n tl	he S	oil S	am	ples	Co	llected	fro	m B	rid	ge N	lo. 3	39 L	ocat	tion					
рі						C	lay									Sie	ve A	analy	ysis			xial est	Bo Sho	ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-9.00	13	DS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	26	67	7	-	-	18.7	30.0	-	-	SM
9.00-12.00	19	SS	Silty Sand	11	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 39											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hď	Chlorides(ppm)	Sulphates (ppm)							
BH-01	12.00	7.83	135.56	120.18							

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

9.00m

13

Loose

30.90 Deg.

* Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 3.00m SPT of the layer 19

Relative Density Medium Dense Angle of Shearing Resistance, φ 32.70 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	15	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 39 AT IR KM 17.170 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 13

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.90 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 21.08$

 $N_{v} = 27.01$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 375.37 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 150.15 kPa

Limited to an allowable bearing pressure per running meter width: 150.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC. Started On: 13/05/2008; Ended On: 15/05/2008 G.W.T: 10.50m

- Star	100		11.13/0	05/2008; Ended On: 15/	SPT - Details raphical Representation of SP								_				
									##		_		516	_		inc)	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value							Relative Density/Consistency	Type of Sample
1.50	0			Filled Up Soil	1.50	3	4	6	10	9						Loose	SS
	•	•		Brownish Loose	3.00	3	6	8	14	o						Loose	SS
6.00	0			Sandy Clayey Silt	4.50 6.00		Colle		10							Loose M.Dense	SS SS
6.00	U				7.50	5	7	11	18							M.Dense	SS
					9.00	5	9	13	22							M.Dense	SS
G.W.	т.	¥			10.50	6	9	13	22							M.Dense	SS
		 		Brownish Medium Dense Silty Clayey Fine Sand	12.00	7	10	13	23		d					M.Dense	SS
		 			13.50	8	12	14	26			o				M.Dense	DS
					15.00	8	12	15	27			o				M.Dense	SS
					17.00	9	11	16	27			o				M.Dense	SS
		 			18.50	10	12	16	28							M.Dense	SS

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At Bridge No. 85

Started On: 13/05/2008: Ended On: 15/05/2008

Start	ed O	n:13/0	05/2008; Ended On: 15/	05/200)8	G.V	N .T:	10.5	0m		
						etail	S	rapl	nical Representation of SP	၁	
								##	10 21 3(4(51 6(7(8) 90	ten	
Depth of Top of	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistenc y	Type of Sample
				20.00	11	13	17	30	9	M.Dense	SS
21.50)			21.50	11	14	18	32	•	Dense	SS
				23.00	11	14	19	33	0	Dense	SS
			Greyish Dense	24.50	10	14	20	34	o	Dense	SS
			Silty Fine Sand	26.00	10	15	22	37		Dense	SS
	 			27.50	12	17	23	40		Dense	SS
30.00)			29.50	14	20	24	44	J	Dense	SS

Bore Hole Terminated at a depth of 30.00m below the existing ground level Fig. 2.1 Soil Profile at Bridge No.85 Location

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 85 Location																											
	ıd						C	lay									Sieve Analysis					axial est		ox ear	(kPa)			
	R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	Id	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
	E.G.L-1.50	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1.50-6.00	12	SS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	17	61	22	14.1	29.9	-	-	-	-	SM
	6.00-21.50	27	SS	Silty Clayey Fine Sand	11	-	-	-	-	2.66	-	18	-	-	M.Dense	0	0	0	78	14	8	-	-	-	-	-	1	SM
2	21.50-30.00	35	SS	Silty Sand	8	-	-	-	-	2.65	_	19	-	_	Dense	0	0	0	75	25	0	-	-	-	1	1	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 85										
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)						
BH-01	12.00	7.83	111.49	89.44						

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 1.50m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 1.50m
SPT of the layer Relative Density Angle of Shearing Resistance, \$\phi\$ -

* Layer-2 (from 1.50m to 6.00m depth below)

Type of Strata Sandy Clayey Silt

ColourBrownishThickness of Layer4.50mSPT of the layer12Relative DensityLooseAngle of Shearing Resistance, φ30.60 Deg.

* Layer-3 (from 6.00m to 21.50m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Brownish
Thickness of Layer 15.50m
SPT of the layer 27

Relative Density Medium Dense Angle of Shearing Resistance, φ 35.10 Deg.

* Layer-4 (from 21.50m to 30.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish

Thickness of Layer 8.50m

SPT of the layer 35
Relative Density Dense
Angle of Shearing Resistance, ϕ 37.375 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level.

Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

	Pile	Carrying	carrying	Load
	(mm)	Capacity	Capacity	carrying
		(kN)	(kN)	Capacity
				(kN)
1	1000	11000	4142	550

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- **3.** The bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level. Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 85 AT IR KM 33.710 (KHURJA - HAFIZPUR SECTION) DESIGN OF PILE FOUNDATION(Refer:BH-01)

Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile

Bored Cast in Situ

1.1 Geometrical Data

Assumed Diameter of pile(D):

Assumed R.L of E.G.L:

Length of pile below E.G.L.(l):

R.L. of Bot. of Pile

1000.0 mm

0.000 m

30.000 m

-30.00 m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1	Laver-I
1.4.1.1	Layer-1

Type of Strata: Filled Up Soil

Average SPT of the strata, N: -

Bulk Density of the strata,γ: 12 kN/m³
Angle of Shearing Resistance,φ: - Deg.
Depth of top of Strata: 0.00 m
Depth of bottom of Strata: 1.50 m
Average Thickness of Strata,I_c: 1.50 m

Effective overburden pressure over the top of strata, σ_{top} : 0.00 kN/m² Effective overburden pressure over the bottom of strata, σ_{bottom} : 3.00 kN/m² Effective overburden pressure at the middle of the strata, σ_{middle} : 1.50 kN/m²

Coeff. Of Earth Pressure,k: 1.00

Skin Resistance of the pile,q_s: Neglected for the fill

1.2.1.2 Layer-II

Type of Strata: Sandy Clayey Silt

Average SPT of the strata, N: 12

Bulk Density of the strata, γ : 15 kN/m³
Angle of Shearing Resistance, ϕ : 30.6 Deg.
Depth of top of Strata: 1.50 m
Depth of bottom of Strata: 6.00 m
Average Thickness of Strata, I_c : 4.50 m

Effective overburden pressure over the top of strata, σ_{top} : 3.00 kN/m²

Effective overburden pressure over the bottom of strata, σ_{bottom} : 25.50 kN/m²

Effective overburden pressure at the middle of the strata, σ_{middle} : 14.25 kN/m²

Coeff. Of Earth Pressure,k: 1.00

Skin Resistance of the pile,q_s: 119.1 kN

 $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$

1.2.1.3 Layer-III

Type of Strata: Silty Clayey Fine Sand

Average SPT of the strata, N: 27

Bulk Density of the strata, γ : 18 kN/m³
Angle of Shearing Resistance, ϕ : 35.1 Deg.
Depth of top of Strata: 6.00 m
Depth of bottom of Strata: 21.50 m
Average Thickness of Strata, I_c : 15.50 m

Effective overburden pressure over the top of strata, σ_{top} : 25.50 kN/m²

Effective overburden pressure over the bottom of strata, σ_{bottom} :	149.50	kN/m ²
Effective overburden pressure at the middle of the strata, σ_{middle} :		kN/m ²
Coeff. Of Earth Pressure,k:		
Skin Resistance of the pile,q _s :		kN
$(q_s: \sigma^*k^*tan\phi^*pi()^*d^*lc)$		
,		
1.2.1.4 Layer-IV		
Type of Strata:	-	
Average SPT of the strata,N:		2
Bulk Density of the strata,γ:		kN/m ³
Angle of Shearing Resistance,φ:		Deg.
Depth of top of Strata:		m
Depth of bottom of Strata:		m
Average Thickness of Strata,I _c :		m
Effective overburden pressure over the top of strata, σ_{top} :		kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom} :	226.00	kN/m ²
Effective overburden pressure at the middle of the strata, σ_{middle} :	187.75	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile,q _s :	5744.6	kN
$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$		
Ultimate Skin Resistance,qs:	10355.5	kN
1.2.2 Computation of End Bearing Resistance:		
Type of Bearing Strata	Silty Sand	
Cross-Sectional Area of pile, Ap:	0.785	m^2
R.L of bottom of pile:	-30.00	
Minimum SPT-value of the Bearing Strata	44	
Angle of Shearing Resistance(ASR)		Degrees
Bearing Capacity Factor(Nq)		
Effective Over Burden Pressure at the bottom of pile (q)		kPa
(limited to a maximum value produced by a soil layer of		
thickness equal to 20 times the diameter of pile from the N.G.L.)		
Ultimate End Bearing Resistance (Qp)	19006 6	kN
(Qp=Ap*q*Nq)	17000.0	KII
1.3.0 Ultimate Load Carrying Capacity (Qu=Qp+q _p)	29362.1	kN
Safe Load Carrying Capacity (Qsafe =Qu/2.5)		kN
However, limit Q_{safe} to the structural capacity of pile:		kN

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at $\label{eq:Km156} Km156\ on\ Eastern\ Freight\ Corridor\ in\ line\ with\ Tender\ No.\ HQ/EN/Pre.\ (Works)/MTC.$ Started On: 11/05/2008; Ended On: 12/05/2008 G.W.T: 10.50m

<u>ડા</u>	arte	u O	n : 11/0	05/2008; Ended On: 12/	03/200	<u> </u>	<u>U.</u>		10.5										
					SP'	T - D	etail	S	rapl	nica	l Re	epi	ese	ntat	ioı	n of	SP	<u></u>	
									##	10	0 20	(3(4(516	(7	(81	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					1.50	3	4	4	8	q								Loose	SS
					3.00	UDS	Colle	cted										Loose	SS
				Brownish Loose Sandy Clayey Silt	4.50	3	4	5	9	٥								Loose	SS
					6.00	4	6	7	13	d								Loose	SS
					7.50	5	6	9	15	(Loose	SS
9	.00		8888		9.00	7	9	10	19		1							M.Dense	SS
G.	w.T	<u></u>		Greyish Medium Dense	10.50	9	11	12	23			\						M.Dense	SS
12	2.00			Silty Fine Sand	12.00	10	14	14	28		1							M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No. 86 Location**

	T	able 2.1	l: Laboratory	y Tes	st R	lesu	ılts	on t	he S	oil S	San	aple	s C	ollected	l fro	m I	Brid	lge]	No.	86 I	Loca	tion					
nd						C	lay									Sie	eve A	Analy	ysis			axial est	Box	Shear	(kPa)		
R.L of Sample below Existing Grou level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	Id	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-9.00	11	SS	Sandy Clayey Silt	13	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	20	70	10	-	-	15.6	29.6	-	-	SM
9.00-12.00	21	SS	Silty Sand	10	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	84	16	0	-	-	-	-	-	-	SM

Table 2.2: Chen Water Sample	•	om Bor		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.87	133.23	121.7

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

9.00m

11

Loose

30.30 Deg.

* Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 3.00m
SPT of the layer 21

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.30 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt but can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	10	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are loose deposits of coarse-grained type in the form of sandy clayey silt but can be considered as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 86 AT IR KM 34.403 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 8

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 29.60 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 17.78$

 $N_{v} = 21.48$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 311.69 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 124.68 kPa

Limited to an allowable bearing pressure per running meter width: 100.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 100kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 100kPa and SPT of 08 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at $\label{eq:Km156} Km156\ on\ Eastern\ Freight\ Corridor\ in\ line\ with\ Tender\ No.\ HQ/EN/Pre.\ (Works)/MTC.$ Started On: 28/05/2008; Ended On: 29/05/2008 G.W.T: 9.00m

<u>ာ</u>	arte	a O	II: 20/0	05/2008; Ended On: 29/	03/200	70	U.1	v .1.	9.00	Ш								
					SP'	T - D	etail	S	rapl	nical	Re	pres	ent	atio	on o	fSP	ý	
									##	10	20	3(4	(5)	60	7(8	90	enc	
Denth of Ton of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
					1.50	7	7	9	16	q							M.Dense	SS
				Brownish	3.00	UDS	Samp	ler Ins	talled								M.Dense	UDS
				Medium Dense Sandy Clayey Silt	4.50	7	10	12	22								M.Dense	SS
					6.00	9	10	15	25								M.Dense	SS
					7.50	10	13	16	29		d						Dense	SS
9	0.00	↓			9.00	13	15	17	32								Dense	SS
				Greyish to Brownish Dense	10.50	13	17	19	36								V.Dense	SS
1	2.00			Silty Fine Sand	12.00	14	20	20	40								V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No. 112 Location**

	,	Table 2	2.1: Laborato	ry Te	st l	Res	ults	on	the	Soil	l Sa	mp	les	Collect	ed 1	fron	n B	ridg	ge N	lo. 1	12 I	Loca	tion				
pu	ample below with the control of the															Sie	ve A	naly	ysis			xial est	Box	Shear	(kPa)		
R.L of Sample below Existing Grou level(m)	of	of	Engineering Classification of	NMC(%)	LL (%)	PL (%)	PI		vity,		Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-9.00	23	SS	Sandy Clayey Silt	9	-	-	-	-	2.7	-	17	-	-	Loose	0	0	0	24	56	20	-	-	21.1	32.8	-	-	SM
9.00-12.00	34	SS	Silty Sand	7	Ŀ	_	_	_	2.7		18	_	_	Dense	0	0	0	78	22	0	_	_	_	_	_	_	SM
7.00 12.00	34	55	Sity Build	,					2.7		10			Delise	, J	3	3	, 0		<u> </u>							5.141

conducted o	on Wate	r Samp	alysis Result le collected f e No. 112	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.89	120.86	100.47

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

9.00m

23

Loose

33.90 Deg.

* Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

 $\begin{array}{ll} \text{Thickness of Layer} & 3.00m \\ \text{SPT of the layer} & 34 \\ \text{Relative Density} & \text{Dense} \\ \text{Angle of Shearing Resistance, } \phi & 37.10 \text{ Deg.} \end{array}$

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the final week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	19	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 112 AT IR KM 46.118 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

 $Type \ of Footing: \ Isolated \ Column \\ Depth \ of foundation \ below \ the E.G.L: \ 2.00 \qquad m \\ Observed \ Maximum \ thickness \ of Filled \ up \ Soil: \ 0.00 \qquad m \\ Effective \ Depth \ of Foundation \ below \ E.G.L: \ 2.00 \qquad m \\ \\$

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 16

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 31.80 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 12.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 23.76$

 $N_{v} = 31.63$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 497.23 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 198.89 kPa

Limited to an allowable bearing pressure per running meter width: 190.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 190kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 190kPa and SPT of 16 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 05/05/2008; Ended On: 05/05/2008 G.W.T: 12.00m

S	ları	eu	OII	. 03/0	05/2008; Ended On: 05/	03/200	70	U.1		12.0									
		T				SP'	T - D	etail	S	rapl	nical l	Rej	pres	entat	ioi	n of	SP	- X:	
										##	10	20	3(4(516	(7	(8)	90	oue	
Depth of Top of	I aver(m)	Eayer(III)	G.W.I.(III)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
					Brownish Medium Dense	1.50	8	10	11	21		q						M.Dense	SS
4	1.00				Sandy Silt	3.00	4	10	12	22		o						M.Dense	SS
			2000		Greyish	4.50	8	10	13	23		d						V.Stiff	SS
	7.50		2222		Very Stiff Silty Clay	7.50	UDS 6	Colle	cted	25								V.Stiff M.Dense	UDS SS
	.30					9.00	5	8	12	20	,							M.Dense	SS
					Brownish Medium Dense Sandy Silt	10.50	9	11	13	24								M.Dense	SS
1	2.00	0			Suity Sit	12.00	12	14	13	27								M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-08 Location**

		Tol	ole 2.1: Labo	rotory				_						os Coll			non	V	ΛΛ	Q T	ooot	ion					
		141	ne 2.1. Labo	ratory	16		lay	nts	OH (ne s		Sai	IIDI	es Con	ecu			naly		<u>o L</u>	Tria	ixial est	Box S	hear	(a)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-4.00	21	SS	Sandy Silt	11	-	-	1	-	2.7	-	16	1	-	M.Dense	0	0	0	45	55	0	13.2	32.2	-	-	-	-	SM
		~~ ~																									
4.00-7.50	23	SS, UDS	Silty Clay	29	70	31	39	1.1	2.67	0.8	18	40	33	V.Stiff	0	0	0	0	28	72	-	-	148.1	14.4	153.3	0.54	СН
7.50-12.00	24	SS	Sandy Silt	9	-	-	-	-	2.7	-	16	-	-	M.Dense	0	0	0	47	50	3	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-08													
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)									
BH-01	12.00	7.81	29.80	81.09									

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.00m depth below)

Type of Strata Sandy Silt
Colour Brownish
Thickness of Layer 4.00m
SPT of the layer 21

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 33.30 Deg.

* Layer-2 (from 4.00m to 7.50m depth below)

Type of Strata

Colour

Greyish
Thickness of Layer

SPT of the layer

Consistency

Very Stiff
Undrained Cohesion, Cu

Silty Clay

Greyish

3.50m

23

Very Stiff

153.33kPa

* Layer-3 (from 7.50m to 12.00m depth below)

Type of Strata Sandy Silt
Colour Brownish
Thickness of Layer 4.50m
SPT of the layer 24

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 34.20 Deg.

The ground water table was encountered at a depth of 12.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic					
	Foundation	Minimum	Capacity	Settlements					
	Structure	Depth of	(t/m^2)	(mm)					
		Footing below							
		N.G.L							
		(m)							
1	Isolated	1.50	22	45					
	Column								
	Footing/								
	Raft								

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 08 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 21

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 33.30 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 28.23$

 $N_{v} = 39.32$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 552.49 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 220.99 kPa

Limited to an allowable bearing pressure per running meter width: 220.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 21 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 05/05/2008: Ended On: 06/05/2008 G.W.T: 12.00m

ာ	arte	a O	$\Pi: US/U$	05/2008; Ended On: 06/	05/200	70	U.1	V . I :	12.0	OIII			
					SP'	Τ - D	fSP	ý					
									##	10 20 30 40 50 60 70 8	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			Relative Density/Consistency	Type of Sample
					1.50	9	13	14	27	Ĵ		M.Dense	SS
					3.00	8	12	10	22	6		M.Dense	SS
				Brownish Medium Dense Sandy Silt	4.50	7	10	13	23	ò		M.Dense	SS
					6.00	6	9	14	23	9		M.Dense	SS
					7.50	7	8	11	19	d		M.Dense	SS
	3.50				9.00	10	13	16	29			V.Stiff	SS
				Greyish Very Stiff Silty Clay	10.50	UDS	Colle	cted				V.Stiff	UDS
1	2.00				12.00	10	14	19	33			Hard	ss

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-09 Location**

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-09 Location													oles Col	llec	ted	froi	n K	М-	09 I	Loca	tion					
pu					Clay							Sieve Analysis						Tria	ixial est	l Box She		(kPa)					
R.L of Sample below Existing Grou level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-8.50	23	SS	Sandy Silt	10	-	-	-	-	2.7	-	16	-	-	M.Dense	0	0	0	41	59	0	14.5	32.6	-	-	-	-	SM
8.50-12.00	29	SS, UDS	Silty Clay	26	68	33	35	1.2	2.66	0.7	18	32	30	V.Stiff	0	0	0	0	31	69	-	-	190.5	13.9	193.3	0.52	СН

conducted or	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-09													
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)										
BH-01	12.00	7.84	23.30	77.93										

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 8.50m depth below)

Type of Strata Sandy Silt
Colour Brownish
Thickness of Layer 8.50m
SPT of the layer 23

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.90 Deg.

* Layer-2 (from 8.50m to 12.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Consistency

Very Stiff

Undrained Cohesion, Cu

Silty Clay

Greyish

3.50m

29

Very Stiff

193.33kPa

The ground water table was encountered at a depth of 12.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic				
	Foundation	Minimum	Capacity	Settlements				
	Structure	Depth of	(t/m^2)	(mm)				
		Footing below						
		N.G.L						
		(m)						
1	Isolated	1.50	26	46				
	Column							
	Footing/Raft							

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 09 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 27

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 35.10 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 33.92$

 $N_{v} = 49.26$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 672.33 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 268.93 kPa

Limited to an allowable bearing pressure per running meter width: 260.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 260kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 260kPa and SPT of 27 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 05/05/2008: Ended On: 06/05/2008 G.W.T: 11.00m

<u> </u>	arte	a O	n : 05/0	05/2008; Ended On: 06/	05/200	J8	G.V		11.0									
					SP'	SPT - Details raphical Representation of SP									ý			
						## 10 2(3(4(5)6(7(8)9)							0	enc				
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
				Brownish	1.50	7	10	13	23		q						V.Stiff	SS
		•		Very Stiff Silty Clay	3.00	UDS	Colle	cted									V.Stiff	UDS
			H		4.50	8	10	16	26								V.Stiff	SS
6.	.00		Н		6.00	6	9	12	21								M.Dense	SS
					7.50	5	10	9	19								M.Dense	SS
				Brownish to Greyish Medium Dense Sandy Clayey Silt	9.00	9	10	14	24			١					M.Dense	SS
10	.50		Ш	Brownish	10.50	11	14	17	31								M.Dense	SS
12	.00			Dense Sandy Silt	12.00	10	13	20	33								M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.3 Soil Profile at KM-10 Location**

			r	Гable 2.1: Lal	borato	ory	Tes	st R	esul	ts o	n the	e So	il S	amj	oles Col	lect	ted f	fron	ı KI	M-1	0 L	ocatio	n					
	ıd						C	lay									Sie	eve A	naly	sis		Triax Tes		Box	Shear	(кРа)		
	R.L of Sample below Existing Grour level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	Id	Consistency, L	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.0	G.L-6.00	24	UDS	Silty Clay	27	77	35	42	1.2	2.65	0.72	19	40	70	V.Stiff	0	0	0	0	22	78	156.5	11.3	-	-	193.3	0.6	СН
6.0	00-10.50	21	SS	Sandy Clayey Silt	11	-	-	1	-	2.67	-	17	1	-	M.Dense	0	0	0	25	65	10	-	-	51.2	32.7	-	-	SM
			~~									10																
10.	50-12.00	32	SS	Sandy Silt	8	-	-	-	-	2.65	-	18	-	-	M.Dense	0	0	0	48	52	0	-	-	-	-	-	-	SM

		•	Results condu com Bore Hol	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	hф	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.81	71.80	80.9

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata

Colour

Brownish
Thickness of Layer

SPT of the layer

Consistency

Set Silty Clay
Brownish
6.00m

SPT of the layer

Very Stiff

Consistency Very Stiff Undrained Cohesion, Cu 153.33kPa

* Layer-2 (from 6.00m to 10.50m depth below)

Type of Strata Sandy Clayey Silt
Colour Brownish to Greyish

Thickness of Layer 4.50m SPT of the layer 21

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.90 Deg.

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata Sandy Silt

Colour Brownish to Greyish

 $\begin{array}{ccc} \text{Thickness of Layer} & 1.50\text{m} \\ \text{SPT of the layer} & 32 \\ \text{Relative Density} & \text{Dense} \\ \text{Angle of Shearing Resistance, } \phi & 36.55 \text{ Deg.} \end{array}$

The ground water table was encountered at a depth of 11.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

If such type of fine-grained strata is considered as bearing strata, the foundation system shall either be coupled with ground replacement technique or located below the zone of **desiccation i.e. dry up** (Normally the zone of desiccation extends up to a maximum depth of 2.50m below the existing ground level).

As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without any ground improvement

technique

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of highly plastic fine-grained strata.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.

The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.50	23	46
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are fine-grained type in the form of highly plastic silty
 clay which can undergo volumetric change phenomenon with the variations in
 seasonal moisture content but are good from both shear and deformation
 considerations to act as bearing strata for the proposed impending loads from
 the superstructure.
- 2. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.
- 3. As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 4. The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.
- 5. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

- 7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 10 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50 Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 2.50 m m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 23

Type of Shear Failure: General

Undrained Cohesion, Cu: 153.33 kPa

1 Design Parameters:

kN/m³ Bulk Density of Soil above the foundation detph (γ_{bulk}) 19.00

Effective Overburden pressure at foundation level (q) 22.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma} = N/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = \quad 1024.57 \;\; kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 409.83 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 260kPa and SPT of 23 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 08/05/2008: Ended On: 08/05/2008 G.W.T: 8.50m

Sta	ute	J O	II . Uo/(05/2008; Ended On: 08/	03/200	70	U.1	v .1.	8.50	1111						
					SP	Γ - D	etail	S	rapl	nical Re	eprese	ntati	on c	of SP	ý	
									##	10 20	3(4(516(7(8	190	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value						Relative Density/Consistency	Type of Sample
					1.50	7	10	12	22	9					V.Stiff	SS
			N		3.00	UDS	Colle	cted							V.Stiff	UDS
				Greyish to Brownish Very Stiff Silty Clay	4.50	5	9	11	20	o					V.Stiff	SS
					6.00	6	9	10	19	0					V.Stiff	SS
					7.50	6	8	13	21	ō					V.Stiff	SS
8.	50	♦			9.00	4	9	14	23						G.W.T M.Dense	SS
				Brownish Medium Dense	9.00	+	7	14	23		١				WI.Delise	دد
10	.50	 		Silty Fine Sand	10.50	8	14	17	31		\				Dense	SS
				Brownish												
12	.00			Dense Silty Fine Sand	12.00	7	15	18	33						Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-18 Location**

		T	able 2.1: Lal	orato	ry '	Tes	st R	esul	lts o	n th	e S	oil S	San	nples C	olle	ecte	d fr	om	KM	[-18	Loca	tion					
ק						C	lay							_		Sie	ve A	nal	ysis		Triaz Tes		Box	Shear	Cu (kPa)		
R.L. of Sample below Existing Grour level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm c}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L-8.50	21	SS	Silty Clay	27	77	33	44	1.1	2.65	0.7	19	33	70	V.Stiff	0	0	0	0	24	76	138.9	12.4	-	-	140.0	0.60	СН
8.50-10.50	23	SS	Silty Sand	8	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	77	23	0	-	-	11.2	32.7	-	-	SM
10.50-12.00	31	SS	Silty Sand	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	74	26	0	-	-	-	-	-	-	SM

Table 2.2: Che on Water Samp		d from		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.84	44.30	74.1

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 8.50m depth below)

Type of Strata Silty Clay

Colour Greyish to Brownish

Thickness of Layer 8.50m

SPT of the layer 21

Consistency Hard

Undrained Cohesion, Cu 140.00kPa

* Layer-2 (from 8.50m to 10.50m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 2.00m
SPT of the layer 23

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.90 Deg.

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Fine Sand

Brownish

1.50m

31

Dense

36.275 Deg.

The ground water table was encountered at a depth of 8.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

If such type of fine-grained strata is considered as bearing strata, the foundation system shall either be coupled with ground replacement technique or located below the zone of **desiccation i.e. dry up** (Normally the zone of desiccation extends up to a maximum depth of 2.50m below the existing ground level).

As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without any ground improvement

technique

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of highly plastic finegrained strata.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.

The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.50	24	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are fine-grained type in the form of highly plastic silty
 clay which can undergo volumetric change phenomenon with the variations in
 seasonal moisture content but are good from both shear and deformation
 considerations to act as bearing strata for the proposed impending loads from
 the superstructure.
- 2. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.
- 3. As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 4. The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.
- 5. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

- 7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 18 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 22

Type of Shear Failure: General

Undrained Cohesion, Cu: 146.67 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 19.00 kN/m^3

Effective Overburden pressure at foundation level (q) 22.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\!\scriptscriptstyle \gamma} = \ N\!/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 980.03 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 392.01 kPa

Limited to an allowable bearing pressure per running meter width: 240.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 22 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At KM-19/4

Started On: 09/05/2008: Ended On: 09/05/2008 G.W.T: 7.00m

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					SP'	T - D	etail	.S	rapl	nical	Re	pre	ese	ntat	io	n o	fSP	ý	
									##	10	20	3(4(516	(7	(8	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					1.50	8	11	15	26		9							V.Stiff	SS
		•		Brownish Very Stiff Silty Clay	3.00	5	9	16	25		o							V.Stiff	SS
					4.50	7	12	15	27		c	•						V.Stiff	SS
					6.00	UDS	Colle	cted										V.Stiff	SS
7.	00	▼			7.50	5	10	16	26		o							G.W.T M.Dense	SS
				Brownish Medium Dense Silty Clayey Fine Sand	9.00	7	11	15	26		q	\						M.Dense	SS
10	.50	 	H	Brownish	10.50	9	14	18	32									Dense	SS
12	.00	 		Dense Silty Fine Sand	12.00	8	15	16	31									Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-19/4 Location**

		Tal	ble 2.1: Labor	ratory [Test	t Re	esul	ts o	n the	e So	il S	amp	les	Collect	ed f	fron	n K	M-1	9/4	Loc	ation						
P						C	lay									Sie	ve A	naly	ysis		Triax Tes		Box	Shear	(kPa)		
R.L of Sample below Existing Grour level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L-6.00	26	UDS	Silty Clay	28	79	33	46	1.1	2.66	0.74	19	44	75	V.Stiff	0	0	0	0	20	80	170.9	12.7	-	-	173.3	0.62	CH
6.00-10.50	26	SS	Silty Clayey Sand	11	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	67	21	12	-	-	21.2	33.4	-	-	SM
				_																							
10.50-12.00	32	SS	Silty Sand	8	-	-	-	-	2.65	-	18	-	-	Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

Table 2.2: Chem Water Sample co		•		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	8.00	7.84	67.40	70.3

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.00m depth below)

Type of Strata

Colour

Brownish
Thickness of Layer

SPT of the layer

Consistency

Very Stiff
Undrained Cohesion, Cu

Silty Clay
Brownish
7.00m

Very Stiff
173.33kPa

* Layer-2 (from 7.00m to 10.50m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Brownish
Thickness of Layer 3.50m
SPT of the layer 26

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.80 Deg.

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 1.50m
SPT of the layer 32
Relative Density Dense
Angle of Shearing Resistance, ϕ 36.55 Deg.

The ground water table was encountered at a depth of 7.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

If such type of fine-grained strata is considered as bearing strata, the foundation system shall either be coupled with ground replacement technique or located below the zone of **desiccation i.e. dry up** (Normally the zone of desiccation extends up to a maximum depth of 2.50m below the existing ground level).

As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without any ground improvement

technique

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of highly plastic finegrained strata.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.

The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.50	27	45
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are fine-grained type in the form of highly plastic silty
 clay which can undergo volumetric change phenomenon with the variations in
 seasonal moisture content but are good from both shear and deformation
 considerations to act as bearing strata for the proposed impending loads from
 the superstructure.
- 2. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.
- 3. As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 4. The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.
- 5. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

- 7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 19/4 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 26

Type of Shear Failure: General

Undrained Cohesion, Cu: 173.33 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 19.00 kN/m^3

Effective Overburden pressure at foundation level (q) 22.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = \ N\!/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma} = \ N/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = \quad 1158.21 \;\; kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 463.29 kPa

Limited to an allowable bearing pressure per running meter width: 270.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 270kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 270kPa and SPT of 26 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 08/05/2008; Ended On: 08/05/2008 G.W.T: 5.50m

31	arte	u O	n : 08/0	05/2008; Ended On: 08/	03/200	<i>J</i> 0	<u>U.1</u>		5.50				
					SP'	Τ - D	etail	S	rapl	nical Represe	entation of SP	- X:	
									##	10 20 30 40	516(7(8190	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			Relative Density/Consistency	Type of Sample
					1.50	7	12	13	25	g		M.Dense	SS
		•			3.00	6	10	16	26	0		M.Dense	SS
				Brownish Medium Dense Silty Fine Sand	4.50	8	13	15	28	o		M.Dense	SS
G.	W.T	. <u>\$</u> .			6.00	7	15	14	29	o		M.Dense	SS
					7.50	9	13	17	30	o		M.Dense	SS
9	.00	 			9.00	8	14	18	32	d		Dense	SS
				Brownish Dense Silty Fine Sand	10.50	10	16	18	34			Dense	SS
1	2.00				12.00	9	12	17	29	J		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-20/5 Location**

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-20/5 Location																										
рг						Cla	ay									Sieve Analysis						axial est	Box S	(kPa)			
R.L of Sample below Existing Groun level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, L _c	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-9.00	28	SS	Silty Sand	10	ı	-	-	-	2.65	-	17	-	-	M.Dense	0	0	0	63	37	0	-	-	21.5	34.2	-	-	SM
0.00.12.00			~						2.11		10								20				20.5	27.0			an t
9.00-12.00	33	SS	Silty Sand	8	-	-	-	-	2.64	-	18	-	-	Dense	0	0	0	61	39	0	-	-	28.6	35.9	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-20/5												
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)								
BH-01	6.00	7.91	20.00	33.54								

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata Silty Fine Sand
Colour Brownish
Thickness of Layer 9.00m
SPT of the layer 28

Relative Density Medium Dense Angle of Shearing Resistance, φ 35.40 Deg.

* Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Brownish Thickness of Layer 3.00m SPT of the layer 33 Relative Density Dense Angle of Shearing Resistance, ϕ 36.825 Deg.

The ground water table was encountered at a depth of 5.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	25	47
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 20/5 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 25

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 34.50 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 31.81$

 $N_{\nu} = 45.47$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 627.44 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 250.98 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 25 are computed to be in the order of 47mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 21/3 - 21/4 (KHURJA - HAFIZPUR SECTION)

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 10/05/2008; Ended On: 10/05/2008 G.W.T: 12.00m

ડા	arte	u O	n : 10/0	05/2008; Ended On: 10/	03/200	<i>J</i> 0	<u>U.</u>	/V . I :	12.0	ull								
					SPT - Details raphical Representation of SP													
									##	10) 2(3(4	(5	16(7(8	190	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
2	.50			Brownish Very Stiff Silty Clay	1.50	4	7	10	17		9						V.Stiff	SS
		•			3.00	3	5	9	14	d							Stiff	SS
				Brownish Stiff	4.50	UDS	Colle	cted									Stiff	UDS
				Silty Clay	6.00	4	6	6	12	q							Stiff	SS
					7.50	6	7	8	15	(Stiff	SS
9	.00		H		9.00	8	9	13	22								V.Stiff	SS
			N	Brownish Very Stiff	10.50	9	12	15	27								V.Stiff	SS
13	2.00	 	M	Silty Clay	12.00	8	12	18	30								V.Stiff	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-21/3-21/4 Location**

IR KM 21/3 - 21/4 (KHURJA - HAFIZPUR SECTION)

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-21/3 to 21/4 Location																										
q						C	lay								Sieve Analysis Triaxial Test Box Shear						(kPa)						
R.L of Sample below Existing Groun level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio. e		િ	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L. 2.50	1.7	aa	G'I. GI	20	7.5	20	15	1.0	2.55	0.6	0 17	20		77 C.100	0	0	0		22	70			110.1	12.0	112.2	0.50	CII
E.G.L-2.50	17	SS	Silty Clay	30	75	30	45	1.0	2.66	0.8	17	30	66	V.Stiff	0	0	0	0	22	78	-	-	113.1	12.9	113.3	0.59	СН
2.50-9.00	14	SS, UDS	Silty Clay	28	77	25	52	0.9	2.68	0.	8 16	-	1-	Stiff	0	0	0	0	21	79	91.7	14.3	-	1	93.3	0.60	СН
9.00-12.00	24	SS	Silty Clay	21	81	28	53	1.1	2.65	0.	6 18	-	<u> </u>	V.Stiff	0	0	0	0	18	82	-	-	-	-	160.0	0.64	СН

	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-21/3 to 21/4												
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)									
BH-01	12.00	7.80	59.30	88.10									

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 2.50m depth below)

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.50m
SPT of the layer	17
Consistency	Very Stiff
Undrained Cohesion, Cu	113.33kPa

* Layer-2 (from 2.50m to 9.00m depth below)

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	6.50m
SPT of the layer	14
Consistency	Stiff
Undrained Cohesion, Cu	93.33kPa

* Layer-3 (from 9.00m to 12.00m depth below)

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	3.50m
SPT of the layer	24
Consistency	Very Stiff
Undrained Cohesion, Cu	160.00kPa

The ground water table was encountered at a depth of 12.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

If such type of fine-grained strata is considered as bearing strata, the foundation system shall either be coupled with ground replacement technique or located below the zone of **desiccation i.e. dry up** (Normally the zone of desiccation extends up to a maximum depth of 2.50m below the existing ground level).

As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without any ground improvement

technique

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of highly plastic finegrained strata.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.

The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.50	20	46
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are fine-grained type in the form of highly plastic silty
 clay which can undergo volumetric change phenomenon with the variations in
 seasonal moisture content but are good from both shear and deformation
 considerations to act as bearing strata for the proposed impending loads from
 the superstructure.
- 2. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.
- 3. As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 4. The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.
- 5. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

- 7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 21/3 - 21/4 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 14

Type of Shear Failure: General

Undrained Cohesion, Cu: 93.33 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 15.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma}=\ N\!/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 623.65 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 249.46 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 14 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 09/05/2008; Ended On: 09/05/2008 G.W.T: 5.00m

Starte	a O	n: 09/0	05/2008; Ended On: 09/	03/200	<i>J</i> 0	U.1	/V . I .	5.00	Ш							
				SPT - Details raphical Representation of SP									y			
					## 10 21 3(4(51 6(7(81 90									suc		
Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value							Relative Density/Consistency	Type of Sample
				1.50	6	6	9	15	q						Loose	SS
			Brownish Loose to Medium Dense	3.00	5	7	10	17	o						M.Dense	SS
G.W.T	Ţ		Silty Fine Sand	4.50	6	7	9	16	0						M.Dense	SS
				6.00	7	7	8	15	4	\					Loose	SS
7.50	 			7.50	7	11	15	26							V.Stiff	SS
			Greyish	9.00	UDS	Colle	cted								V.Stiff	SS
			Very Stiff Silty Clay mixed with Kankars	10.50	10	13	16	29							V.Stiff	UDS
12.00				12.00	9	11	15	26							Hard	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-22/5 Location**

		Tabl	e 2.1: Labora	tory T	est	Re	sult	S OI	1 the	Soi	l S	amp	les	Collecte	ed f	ron	ı Kl	M-2	2/5	Loc	catio	n					
pu						C	lay									Sie	ve A	nal	ysis	1		axial est	Box S	hear	E		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-7.50	16	SS	Silty Sand	10	-	-	-	-	2.66	-	16	-	-	M.Dense	0	0	0	78	22	0	16.5	31.2	-	-	-	-	SM
7.50-12.00	28	SS, UDS	Silty Clay mixed with Kankars	24	70	35	35	1.3	2.65	0.64	19	-	-	V.Stiff	17	0	0	0	21	62	-	-	185.3	18.5	186.6	0.54	СН

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-22/5												
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нd	Chlorides(ppm)	Sulphates (ppm)								
BH-01	6.00	7.82	40.80	74.3								

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)

Type of Strata Silty Fine Sand
Colour Brownish
Thickness of Layer 7.50m
SPT of the layer 16

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 31.80 Deg.

* Layer-2 (from 7.50m to 12.00m depth below)

Type of Strata Silty Clay mixed with

Kankars

Colour Greyish
Thickness of Layer 4.50m
SPT of the layer 28

Consistency Very Stiff Undrained Cohesion, Cu 186.67kPa

The ground water table was encountered at a depth of 5.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.20m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.20m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.20	20	40
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.20m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.20m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 22/5 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.20 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.20 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 15

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 31.50 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 13.20 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 22.87$

 $N_{v} = 30.09$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 512.81 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 205.12 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 15 are computed to be in the order of 40mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 10/05/2008; Ended On: 10/05/2008 G.W.T: 3.00m

- 5	arı	cu	. 0.	11.10/(05/2008; Ended On: 10/					3.00										
						SP'	Γ - D	etail	S	rapl	nica	ıl R	epr	rese	ntat	io	n o	fSP	<u>></u>	
										##	1	0 2	(3((4(516	(7	(8)	90	enc	
Depth of Top of	I ayer(m)	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
2	2.50)			Brownish Medium Dense Silty Fine Sand	1.50	7	7	10	17	/	1							M.Dense	SS
G.	W.	Т	Ŧ			3.00	2	2	2	4	4								Loose	SS
		-			Greyish Loose Sandy Clayey silt	4.50	4	6 Failed	6	12									Loose Loose	SS
6	5.50	,				0.00	UDS	ranec	İ			1							Loose	33
						7.50	6	9	13	22									M.Dense	SS
		}			Brownish to Greyish Medium Dense	9.00	5	9	12	21		o							M.Dense	SS
		-			Sandy Clayey Silt	10.50	7	9	13	22		o							M.Dense	SS
1	2.00	0				12.00	6	10	14	24		o	}						M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-23/1 Location**

IR KM 23/1 (KHURJA - HAFIZPUR SECTION)

Ī	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-23/1 Location																											
	R.L. of Sample below Existing Ground level(m)	Sample		Visual & Engineering Classification of Soil		l'esi		lay	Ic	Gravity, G	9	kN/m³		Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis					Tria To	est	Shear		ned Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification	
	R.L of S level(m)	SPT of S	Type of Sample		NMC(%)	TT (%)	PL (%)	PI	Consistency,	Specific	Void Ratio,	Bulk Density,	Free Swell (%)	Swelling	Relative	Gravel (%)	Coarse (%)	Medium	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined	Consolid	IS-Class
-	E.G.L-2.50	17	SS	Silty Sand	11	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	71	29	0	-	-	23.1	31.9	-	-	SM
=	2.50-6.50	8	SS, UDS	Sandy Clayey Silt	17	33	14	19	0.8	2.68	-	14	-	1	Loose	0	0	0	11	55	34	16.6	28.1	-	-	-	-	SM
	6.50-12.00	21	SS	Sandy Clayey Silt	14	27	15	12	1.1	2.66	-	17	-	-	M.Dense	0	0	0	15	59	26	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-23/1												
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)								
BH-01	6.00	7.81	59.50	89.3								

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 2.50m depth below)

Type of Strata Silty Fine Sand
Colour Brownish
Thickness of Layer 2.50m
SPT of the layer 17

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 32.10 Deg.

* Layer-2 (from 2.50m to 6.50m depth below)

Type of Strata Sandy Clayey Silt

Colour Greyish
Thickness of Layer 4.00m
SPT of the layer 08
Relative Density Loose
Angle of Shearing Resistance, φ 29.60 Deg.

* Layer-3 (from 6.50m to 12.00m depth below)

Type of Strata Sandy Clayey Silt
Colour Brownish to Greyish

Thickness of Layer 5.50m SPT of the layer 21

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.30 Deg.

The ground water table was encountered at a depth of 3.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	<u>MAXIMUM</u>	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	16	32
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

Considering the weak sub-soil strata lying underneath the recommended bearing stratum, the maximum depth of the foundation system is recommended above. In no case, the recommended depth shall be increased further.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. Considering the weak sub-soil strata lying underneath the recommended bearing stratum, the maximum depth of the foundation system is recommended above. In no case, the recommended depth shall be increased further.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 23/1 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 17

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 32.10 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 9.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 24.66$

 $N_{v} = 33.16$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 421.16 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 168.46 kPa

Limited to an allowable bearing pressure per running meter width: 160.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 17 are computed to be in the order of 32mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 11/05/2008: Ended On: 11/05/2008 G.W.T: 10.00m

31	arte	u O	n:11/(05/2008; Ended On: 11/	05/200	J8	Ū.١	V.I:	10.0	om							
					SPT - Details raphical Representation of SP											.y	
						## 10 213(4(516(7(8190											
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value							Relative Density/Consistency	Type of Sample
					1.50	7	9	10	19	٩						M.Dense	SS
		•			3.00	8	10	13	23							M.Dense	SS
				Brownish Medium Dense	4.50	6	11	16	27							M.Dense	SS
				Silty Clayey Fine Sand	6.00	UDS	Colle	cted								M.Dense	UDS
					7.50	12	10	13	23	q						M.Dense	SS
9	.00				9.00	12	15	17	32		}					Hard	SS
G.	W.T	<u>↓</u>		Greyish to Brownish Very Stiff to Hard Silty Clay mixed with Kankars	10.50	8	11	19	30		d					V.Stiff	SS
13	2.00				12.00	13	16	20	36							Hard	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-24 Location**

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-24 Location																										
pu						C	lay									Sieve Analysis					Triaxial Test		ox ear	(kPa)			
R.L. of Sample below Existing Grou level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)		PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-9.00	23	SS, UDS	Silty Sand	8	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	79	21	0	11.9	32.7	-	-	-	-	SM
9.00-12.00	32	SS	Silty Clay mixed with Kankars	22	75	31	44	1.2	2.65	-	20	-	-	V.Stiff	19	0	0	0	17	64	-	-	-	-	213	0.59	СН

Table 2.2: Ch Water Sampl		•		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.00	7.84	21.30	80.11

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 9.00m
SPT of the layer 23

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.90 Deg.

* Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata Silty Clay mixed with

Kankars

Colour Greyish to Brownish

Thickness of Layer 3.00m
SPT of the layer 32
Consistency Hard
Undrained Cohesion, Cu 213.33kPa

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	20	40
	Column			
	Footing/			
	Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 24 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 19

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 32.70 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 26.45$

 $N_{v} = 36.24$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 515.01 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 206.00 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 19 are computed to be in the order of 40mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 12/05/2008; Ended On: 12/05/2008 G.W.T: 9.50m

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					SP	SPT - Details raphical Representation of SP											cy		
									##	10) 2(3(4	1(5	16(7(8	319()	en	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
1.	70			Filled Up Soil	1.50	SPT 1	Negleo	cted fo	or the	fill La	ayer							-	DS
		•			3.00	4	5	7	12	q								Stiff	SS
				Brownish Stiff	4.50	UDS	Colle	cted										Stiff	UDS
				Silty Clay	6.00	4	6	9	15	(2)							Stiff	SS
					7.50	6	6	7	13	d								Stiff	SS
	00		\mathbb{N}		9.00	5	7	10	17								-	M.Dense	SS
G.V	V.T			Greyish							/								
1				Medium Dense							,								
10	.50	ļ		Silty Fine Sand	10.50	11	15	19	34			q						Dense	SS
1			1 1	Greyish to Brownish															
				Dense															
12	.00		488	Silty Fine Sand	12.00	6	10	25	35			J						Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-25 Location**

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-25 Location																										
nd						C	lay									Sieve Analysis						axial est		Box Shear			
R.L of Sample below Existing Grou level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-1.70	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.70-9.00	13	SS, UDS	Silty Clay	33	80	21	59	0.8	2.68	0.9	16	65	53	Stiff	0	0	0	0	21	79	81.4	8.7	_	_	86.0	0.63	СН
1.70 9.00	13	55, 625	Sitty City	33	50			0.0	2.00	0.7	10	- 55	33	Sim	3	,	,	-	-1	,,	01.7	0.7			00.0	0.03	
9.00-10.50	17	SS	Silty Sand	9	-	-	-	-	2.67	0.2	16	_	-	M.Dense	0	0	0	81	19	0	-	-	13.2	30.9	-	-	SM
10.50-12.00	34	SS	Silty Sand	7	-	-	-	-	2.65	0.2	18	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-25													
Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)										
BH-01	10.50	7.79	100.84	154.83										

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 1.70m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 1.70m

* Layer-2 (from 1.70m to 9.00m depth below)

Type of Strata Silty Clay
Colour Brownish
Thickness of Layer 7.30m
SPT of the layer 13
Consistency Stiff
Undrained Cohesion, Cu 86.67kPa

* Layer-3 (from 9.00m to 10.50m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 17

Relative Density Medium Dense

Angle of Shearing Resistance 32.10°

* Layer-4 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand
Colour Greyish to Brownish

Thickness of Layer 1.50m SPT of the layer 34
Relative Density Dense Angle of Shearing Resistance 37.10°

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately below the filled up soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

As the thickness of fill is 1.70m, the foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L) i.e. 4.20m below the existing ground level.

Hence, the foundation system can be raft located at a depth of 4.20m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	18	62

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. As the thickness of fill is 1.70m, the foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L) i.e. 4.20m below the existing ground level.
- 3. The foundation system can be raft located at a depth of 4.20m below the existing ground level (E.G.L).
- 4. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 5. The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 25 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 4.20 m

Observed Maximum thickness of Filled up Soil: 1.70 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 12

Type of Shear Failure: General

Undrained Cohesion, Cu: 80.00 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 15.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = \ N\!/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma} = N/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 534.56 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 213.82 kPa

Limited to an allowable bearing pressure per running meter width: 180.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 180kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 180kPa and SPT of 12 are computed to be in the order of 62mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 12/05/2008; Ended On: 12/05/2008 G.W.T: 10.00m

Ste	arte	u O	11.12/0	05/2008; Ended On: 12/	03/200	70	U.1	W . I .	10.0	ш								
					SP'	T - D	etail	S	rapl	nical	Re	pres	ent	tati	on (ofSP	y	
									##	10	20	3(4	(50	6(7(8	3190	suc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
2.	00			Brownish Loose Sandy Silt	1.50	4	6	7	13	1							Loose	SS
		•			3.00	4	7	9	16	(M.Dense	SS
					4.50	5	5	8	13	q							Loose	SS
				Brownish Medium Dense Sandy Clayey Silt	6.00	5	8	8	16	Ó	,						M.Dense	SS
					7.50	6	7	10	17	,							M.Dense	SS
10	.00	¥			9.00	5	9	11	20		1						M.Dense	SS
10	.00			Greyish to Brownish	10.50	9	14	19	33		•						Dense	SS
12	.00			Medium Dense Silty Fine Sand	12.00	10	16	22	38								Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.26/3 Location**

		Table 2	2.1: Laborato	ory Test	Re	sult	ts o	n th	e So	oil S	am	ples	Co	llected	fro	m I	ΚM	. 26	/3 I	oca	ation	ì					
pı						C	lay									Sie	ve A	nal	ysis			axial est	Bo Sho	ox ear	Cu (kPa)		
R.L of Sample below Existing Groun level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	Id	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	pression Tests,					IS-Classification							
E.G.L-2.00	13	SS	Sandy Silt	14	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	21	65	14	-	-	-	-	-	-	SM
2.00-10.00	16	SS	Sandy Clayey Silt	12	-	-	-	-	2.7	-	16	-	-	M.Dense	0	0	0	22	58	20	-	-	18.7	31.2	-	-	SM
10.00.12.00	22		g:: g .								10			-					20								g) f
10.00-12.00	33	SS	Silty Sand	9	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	80	20	0	-	-	-	-	-	-	SM

1		•	esults conduc re Hole at K	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.81	101.32	100.46

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 2.00m depth below)

Type of Strata Sandy Silt Colour Brownish Thickness of Layer 2.00m SPT of the layer 13 Relative Density Loose Angle of Shearing Resistance, ϕ 30.90 Deg.

* Layer-2 (from 2.00m to 10.00m depth below)

Type of Strata Sandy Clayey Silt

ColourBrownishThickness of Layer8.00mSPT of the layer16

Relative Density Medium Dense Angle of Shearing Resistance, φ 31.80 Deg.

* Layer-3 (from 10.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 2.00m
SPT of the layer 33
Relative Density Dense
Angle of Shearing Resistance, φ 36.825 Deg.

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the

sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	19	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 26/3 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 16

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 31.80 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 12.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 23.76$

 $N_{v} = 31.63$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 497.23 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 198.89 kPa

Limited to an allowable bearing pressure per running meter width: 190.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 190kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 190kPa and SPT of 16 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at\ Km\ 156\ on\ Eastern\ Freight\ Corridor\ in\ line\ with\ Tender\ No.\ HQ/EN/Pre.\ (Works)/MTC.$

Started On: 13/05/2008; Ended On: 13/05/2008 G.W.T: 9.50m

ડા	arte	u O	H: 15/0	05/2008; Ended On: 13/	05/200	78	Ū.١	/V . I :	9.50	m								
					SP'	Γ - D	etail	S	rapl	nical	Re	pres	enta	itio	n o	fSP	%	
									##	10	20	3(4	(51	6(7	7(8)	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
				Greyish to Brownish	1.50	4	5	4	9	٩							Stiff	SS
		•		Stiff Silty Clay	3.00	4	7	8	15	Ì	}						Stiff	SS
					4.50	5	7	8	15	C	;						Stiff	SS
6	.00				6.00	5	8	9	17		d						V.Stiff	SS
				Greyish to Brownish Very Stiff Silty Clay	7.50	5	8	11	19								V.Stiff	SS
_	.00				9.00	6	11	13	24		ł						M.Dense	SS
G.	W.T	<u>+</u> 		Greyish to Brownish Medium Dense	10.50	8	12	17	29		1						M.Dense	SS
12	.00			Silty Clayey Fine Sand	12.00	9	15	22	37			1					Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at Bridge No.27/4-27/3 Location

IR KM 27/4 - 27/3 (KHURJA - HAFIZPUR SECTION)

		Table	2.1: Laborat	ory Tes	st R	esu	lts	on t	he S	oil S	San	ples	s C	ollected	fro	m I	KM-	-27/	4-27	7/3 I	∟ocati	on					
pu						Cl	lay									Sie	ve A	naly	ysis		Triaz Tes			ox ear	(kPa)		
R.L of Sample below Existing Groulevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	### ### ##############################						ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification														
E C L 6 00	12	GG LIDG	G'14 G1	20	70	27	~ 1	0.0	2.60	1.00	1.0	70		av.cc	0				2.1	76	00.0	0.7			967	0.61	CII
E.G.L-6.00	13	SS, UDS	Silty Clay	38	78	21	51	0.8	2.68	1.02	16	70	33	Stiff	0	0	U	0	24	76	80.9	8.7	-	-	86.7	0.61	СН
6.00-9.00	18	SS	Silty Clay	31	77	33	44	1.0	2.66	0.82	18	-	-	V.Stiff	0	0	0	0	22	78	-	-	-	-	120.0	0.60	СН
9.00-12.00	26	SS	Silty Sand	7		_		_	2 66	0.19	17	_		M.Dense	0	0	0	79	13	8	_	_		-	_	_	SM
7.00-12.00	20	55	Sifty Sailu	,		_	1	_	2.00	0.19	1/	_		WI.Delise	0	0	U	13	13	0	-	_				-	SIVI

	ple collected	•	sults conduct e Hole at KM	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.78	120.94	150.03

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata Silty Clay

Colour Greyish to Brownish

Thickness of Layer 6.00m

SPT of the layer 13

Consistency Stiff

Undrained Cohesion, Cu 86.67kPa

* Layer-2 (from 6.00m to 9.00m depth below)

Type of Strata Silty Clay

Colour Greyish to Brownish

Thickness of Layer 3.00m SPT of the layer 18

Consistency Very Stiff Undrained Cohesion, Cu 120.00kPa

* Layer-3 (from 9.00m to 12.00m depth below)

Type of Strata Silty Clayey Fine Sand Colour Greyish to Brownish

Thickness of Layer 3.00m SPT of the layer 26

Relative Density Medium Dense

Angle of Shearing Resistance 34.80°

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	18	62

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 27/4 - 27/3 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

m

Depth of foundation below the E.G.L: 2.50 m Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 12

Type of Shear Failure: General

Undrained Cohesion, Cu: 80.00 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 15.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma} = N/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 534.56 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 213.82 kPa

Limited to an allowable bearing pressure per running meter width: 180.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 180kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 180kPa and SPT of 12 are computed to be in the order of 62mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC. Started On: 14/05/2008; Ended On: 14/05/2008 G.W.T: 10.50m

Sta	ute	u O	11.14/(05/2008; Ended On: 14/					10.5								
					SP	Τ - D	etail	S	rapl	nical l	Rep	rese	ntat	ion (ofSP	>	
									##	10	2(3	3(4(5160	7(8	3190	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value							Relative Density/Consistency	Type of Sample
					1.50	4	7	9	16	٩						V.Stiff	SS
		4		Greyish to Brownish	3.00	6	8	11	19	o	•					V.Stiff	SS
				Very Stiff Silty Clay	4.50	7	7	10	17	o						V.Stiff	SS
					6.00	UDS	Colle	cted								V.Stiff	SS
					7.50	5	7	9	16	ō						V.Stiff	SS
					9.00	7	10	10	20							V.Stiff	SS
10	.50	ţ		Carrich	10.50	8	13	21	34			٩				Dense	SS
				Greyish Dense													
12	.00			Silty Fine Sand	12.00	10	17	19	36							Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.28 Location**

			Table 2.1: Lab	oratory T	est	Res	sult	s on	the	Soi	l Sa	mpl	es (Collecte	ed fi	om	KN	M-2	8 L	cati	ion						
pun						C	lay									Sie	ve A	\nal _\	ysis		Triax Tes			ox ear	ı (kPa)		
R.L. of Sample below Existing Grolevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, C	Consolidation Tests, Cc	IS-Classification
E.G.L-10.50	18	SS, UDS	Silty Clay	28	75	33	12	1 1	2 67	0.7	16	65	18	V.Stiff	0	0	0	0	22	78	114.5	7.8			120.0	0.59	СН
L.G.L-10.30	10	55, CD5	Sincy Clay	20	13	33	74	1.1	2.07	0.7	10	0.5	70	v .5tm	0	0	0	0	22	70	114.5	7.0			120.0	0.33	CII
10.50-12.00	34	SS	Silty Sand	8	-	-	-	-	2.66	0.2	17	-	-	Dense	0	0	0	78	22	0	-	-	-	1	-	-	SM

		•	Its conducted of Hole at KM-28	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.80	116.54	134.56

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 10.50m depth below)

Type of Strata Silty Clay

Colour Greyish to Brownish

Thickness of Layer 6.00m SPT of the layer 18

Consistency Very Stiff
Undrained Cohesion, Cu 120.00kPa

* Layer-2 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 34
Relative Density Dense
Angle of Shearing Resistance 37.10°

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	23	66

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 28 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 16

Type of Shear Failure: General

Undrained Cohesion, Cu: 106.67 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 15.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = \ N\!/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma} = N/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 712.75 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 285.10 kPa

Limited to an allowable bearing pressure per running meter width: 230.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 230kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 230kPa and SPT of 16 are computed to be in the order of 66mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

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Started On: 14/05/2008; Ended On: 14/05/2008 G.W.T: 10.50m

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					SPT - Details raphical Representation of SF							ıcy							
J						ππ 10 21 31 41 31 01 71 31 31											90	ster	0
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
2.	00			Brownish Stiff Silty Clay	1.50	4	7	7	14		ĵ	-	-		-			Stiff	SS
					3.00	3	3	5	8									M.Stiff	SS
				Brownish	4.50	UDS	Colle	cted										V.Stiff	SS
				Medium Stiff Silty Clay	6.00	2	3	3	6	o								Stiff	SS
					7.50	2	3	5	8	$\left \begin{array}{c} \downarrow \\ \downarrow \end{array} \right $	\							M.Stiff	SS
9.	00		逛		9.00	6	8	13	21		1							M.Dense	SS
1				Brownish to Greyish															
1		١.		Medium Dense								/	\					_	
10	.50	₩		Silty Fine Sand	10.50	12	17	22	39				4					Dense	SS
1				Greyish									'						
1	0.0			Dense	12.00			2.4						/				V.Dense	99
12	.00	 _		Silty Fine Sand	12.00	18	29	34	63					8	•			v.Delise	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.28/14 Location**

IR KM 28/14 (KHURJA - HAFIZPUR SECTION)

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-28/14 Location																										
pun						С	lay									Sie	ve A	naly	ysis		Triax Test Re			ox ear	(kPa)		
R.L. of Sample below Existing Grot level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	♦ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-2.00	1.4	CC LIDC	Cilty Class	26	77	24	53	1.0	2.67	0.69	16	65	48	Stiff	0	0	0	0	24	76	90.2	8.7			93.3	0.60	СН
E.G.L-2.00	14	SS, UDS	Silty Clay	26	//	24	33	1.0	2.07	0.69	10	03	48	Sulli	U	U	U	0	24	76	90.2	8.7	-	-	93.3	0.60	CH
2.00-9.00	7	SS	Silty Clay	31	80	21	59	0.8	2.68	0.83	15	65	48	M.Stiff	0	0	0	0	21	79	43.2	4.5	-	-	46.7	0.63	СН
9.00-10.50	21	SS	Silty Sand	8	-	-	-	-	2.66	0.21	17	-	-	Dense	0	0	0	80	20	0	-	-	-	-	-	-	SM
10.50-12.00	39	SS	Silty Sand	8	-	-	-	-	2.65	0.21	19	-	-	Dense	0	0	0	76	24	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-28/14									
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)					
BH-01	10.50	7.82	111.21	131.94					

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 2.00m depth below)

Type of Strata

Colour

Brownish
Thickness of Layer

SPT of the layer

Consistency

Undrained Cohesion, Cu

Silty Clay
Brownish
2.00m

Stiff

93.33kPa

* Layer-2 (from 2.00m to 9.00m depth below)

Type of Strata Silty Clay
Colour Brownish
Thickness of Layer 7.00m
SPT of the layer 07

Consistency Medium Stiff Undrained Cohesion, Cu 46.67kPa

* Layer-3 (from 9.00m to 10.50m depth below)

Type of Strata Silty Fine Sand
Colour Brownish to Greyish

Thickness of Layer 1.50m SPT of the layer 21

Relative Density Medium Dense

Angle of Shearing Resistance 37.10°

* Layer-4 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 39

Relative Density Dense Angle of Shearing Resistance 38.475°

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	14	66

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 28/14 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

m

Depth of foundation below the E.G.L: 2.50

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 8

Type of Shear Failure: General

Undrained Cohesion, Cu: 53.33 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 12.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = \ N\!/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma} = N/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 356.37 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 142.55 kPa

Limited to an allowable bearing pressure per running meter width: 140.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 140kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 140kPa and SPT of 08 are computed to be in the order of 66mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 15/05/2008; Ended On: 15/05/2008 G.W.T: 10.50m

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									##	10) 2(3(4(5	516(7(80	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					1.50	8	10	13	23		9							V.Stiff	SS
					3.00	UDS	Colle	cted										V.Stiff	SS
				Brownish Very Stiff Silty Clay	4.50	11	13	16	29			9						V.Stiff	ss
					6.00	12	15	17	32									Hard	SS
					7.50	8	10	13	23		d	/						V.Stiff	SS
					9.00	9	12	14	26									V.Stiff	SS
10	.50	¥		Greyish	10.50	12	17	21	38			7	\					Dense	SS
12	.00			Dense Silty Fine Sand	12.00	14	26	33	59				'	\				V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.30 Location**

		Tah	le 2.1: Labor											Collect		fro	m k	M.	30		ation						
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)			ay	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	(9)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)			Fine (%)			Triax Test Re			ear ox	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-10.50	27	SS, UDS	Silty Clay	21	75	31	44	1.2	2.65	0.6	19	64	45	V.Stiff	0	0	0	0	24	76	175.4	9.8	-	-	180.0	0.59	СН
10.50-12.00	38	SS	Silty Sand	8	_	-	-	-	2.66	0.2	17	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

		•	sults conduct re Hole at K	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.88	94.57	100.35

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 10.50m depth below)

Type of Strata

Colour

Brownish
Thickness of Layer

SPT of the layer

Consistency

Undrained Cohesion, Cu

Silty Clay
Brownish

10.50m

27

Very Stiff
Undrained Cohesion, Cu

180.00kPa

* Layer-2 (from 10.50m to 12.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Silty Fine Sand

Greyish

1.50m

38

Dense

Angle of Shearing Resistance 38.20°

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	30	63

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 30 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 23

Type of Shear Failure: General

Undrained Cohesion, Cu: 153.33 kPa

1 Design Parameters:

kN/m³ Bulk Density of Soil above the foundation detph (γ_{bulk}) 19.00

Effective Overburden pressure at foundation level (q) 22.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma} = N/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = \quad 1024.57 \;\; kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 409.83 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 23 are computed to be in the order of 63mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 16/05/2008; Ended On: 16/05/2008 G.W.T: 10.50m

					SP'	T - D	etail	S	irapi	nica	ıl R	lep	res	sen	tat	io	n o	fSP	>	
									##	1	0 2	213	3(4	(5	161	(7	(8)	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value										Relative Density/Consistency	Type of Sample
					1.50	8	10	9	19		9								M.Dense	SS
		^			3.00	7	10	14	24		,								M.Dense	SS
				Brownish Medium Dense Silty Fine Sand	4.50	9	12	14	26										M.Dense	SS
					6.00	8	13	15	28										M.Dense	SS
					7.50	7	12	11	23		(M.Dense	SS
					9.00	10	11	16	27										M.Dense	SS
10	.50	¥		Greyish	10.50	12	15	18	33			,		\					Dense	SS
12	.00			Dense Silty Fine Sand	12.00	17	28	39	67					`	\	6			V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.31 Location**

		Tab	le 2.1: Labora	atory T	'est	Re	sult	s on	the	Soi	l Sa	mpl	les	Collecte	ed f	rom	KN	1.3 1	l Lo	cati	on						
pur						C	lay									Sie	eve A	\naly	ysis			axial est	Be Sh	ox ear	ı (kPa)		
R.L of Sample below Existing Grolevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Ct	Consolidation Tests, Cc	IS-Classification
E.G.L-10.50	25	SS	Silty Sand	9	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	81	19	0	-	-	13.2	33.8	-	-	SM
10.50-12.00	33	SS	Silty Sand	7	_	_	_		2.66		18			Dense	0	0	0	77	23	0			_				SM
10.30-12.00	33	သပ	Sifty Sand	/	_		_	_	2.00		10	_		Dense	U		U	//	23	U	_	_	_	_		_	21/1

		•	sults conduct re Hole at K	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.79	88.65	112.11

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 10.50m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 10.50m
SPT of the layer 25

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.50 Deg.

* Layer-2 (from 10.50m to 12.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Fine Sand

Greyish

1.50m

33

Dense

36.825 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	22	44
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 31 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 19

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 32.70 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 12.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 26.45$

 $N_{v} = 36.24$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 557.52 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 223.01 kPa

Limited to an allowable bearing pressure per running meter width: 220.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 19 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 21/05/2008: Ended On: 21/05/2008 G.W.T: 9.00m

2	arte	a O	n: 21/0	05/2008; Ended On: 21/	05/200	Jð	U.1	/V . I :	9.00	/111		
					SP'	T - D	etail	.s	rapl	nical Representation of SP	y	
									##	10 21 31 41 51 61 71 81 90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
					1.50	7	8	10	18	ĵ	M.Dense	SS
				Brownish Medium Dense Sandy Clayey Silt	3.00	9	11	13	24		M.Dense	SS
					4.50	8	11	13	24	\ \	M.Dense	SS
6	5.00				6.00	14	16	17	33	•	Dense	SS
				Brownish Dense Sandy Silt	7.50	13	17	15	32		Dense	SS
9	.00	¥			9.00	20	24	27	51	0	V.Dense	SS
				Greyish Very Dense Silty Fine Sand	10.50	22	31	39	70		V.Dense	SS
1	2.00	<u> </u>			12.00	20	29	40	69	ļ	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.32 Location**

IR KM 32 (KHURJA - HAFIZPUR SECTION)

		Tab	le 2.1: Labora	atory T	'est	Re	sult	s or	ı the	Soi	l Sa	mp	les	Collecte	ed f	ron	ı Kl	M.3	2 L	ocat	tion						
pu						C	lay									Sie	ve A	naly	ysis			axial est		ox ear	(kPa)		
R.L of Sample below Existing Groun level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-6.00	22	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	23	54	23	-	-	14.5	32.7	-	-	SM
																									<u> </u>		
6.00-9.00	32	SS	Sandy Silt	8	-	-	-	-	2.66	-	18	-	-	Dense	0	0	0	26	74	0	-	-	-	-	-	-	SM
9.00-12.00	60	SS	Silty Sand	5	_	_			2.65		20			V.Dense	0	0	0	71	29	0			_				SM
9.00-12.00	00	22	Siny Sand	3	_	_	-		2.03	_	20	_	Ė	v.Delise	U	0	0	/1	29	0	-	-	_		-	_	SIVI

		•	esults conduc ore Hole at K	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.81	84.56	104.34

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

22

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.60 Deg.

* Layer-2 (from 6.00m to 9.00m depth below)

Type of Strata
Colour
Brownish
Thickness of Layer
SPT of the layer
32

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 36.55 Deg.

* Layer-3 (from 9.00m to 12.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Polyting Density

Silty Fine Sand

Greyish

3.00m

SPT of the layer

60

Very Dense

Relative Density Very Dense Angle of Shearing Resistance, φ 42.560 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	21	44
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 32 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 2.00 m m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 18

Type of Shear Failure: General

Angle of Shearing Resistance, ϕ : 32.40 Deg.

1 Design Parameters:

kN/m³ Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00

Effective Overburden pressure at foundation level (q) 12.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 25.55$

 $N_{v} = 34.70$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 537.42 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 214.97 kPa

Limited to an allowable bearing pressure per running meter width: 210.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 210kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 210kPa and SPT of 18 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at $\label{eq:Km156} Km156\ on\ Eastern\ Freight\ Corridor\ in\ line\ with\ Tender\ No.\ HQ/EN/Pre.\ (Works)/MTC.$ $\ Started\ On: 16/06/2008;\quad Ended\ On: 18/06/2008\quad G.W.T:\ 5.00m$

Sta	ricc	1 0	11.10/	06/2008; Ended On: 18/	SPT - Details raphical Representation of SP													SP		
					## 10 2(3(4(5)6(7(8)9)								_	ncy						
Jo									<u> </u>	ΙÌ		T	Ï				1	, 0	iste	le
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value										Relative Density/Consistency	Type of Sample
		П												<u> </u>						
				Brownish Loose	1.50	3	4	7	11	q									Loose	SS
		`		Sandy Clayey Silt	3.00	UDS	Colle	cted											Loose	SS
4.5 G.W	_	¥	14		4.50	4	6	11	17		9								M.Dense	SS
G.W	.1	. <u>▼</u> - 			6.00	6	8	12	20										M.Dense	SS
			П	Greyish to Brownish	7.50	7	9	14	23		}								M.Dense	SS
		 		Medium Dense Silty Fine Sand	9.00	7	10	14	24		o	١							M.Dense	SS
		 	Н		11.00	9	12	16	28										M.Dense	SS
12.:	50		11		12.50	11	14	19	33										Dense	SS
		 		Brownish	14.00	12	15	22	37				(Dense	DS
		 		Dense Silty Fine to Medium Coarse Sand	15.50	13	16	26	42										Dense	SS
		 			17.00	14	16	27	43										Dense	SS
		 			18.50	14	18	29	47					1					Dense	SS
19.0	00																			

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At KM.33 (10-11)

Started On: 16/06/2008: Ended On: 18/06/2008

Sta	arte	<u> </u>	n : 16/0	06/2008; Ended On: 18/	(06/200)8	G.V	<u> </u>	5.00	m										
					SP'	Γ - D	etail	S	raph	nical	Rep	rese	enta	tio	n o	fSP	၂င			
									##	10	203	3(4(516	(7	7(8	90		ten		
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative	Density/Consistenc	y	Type of Sample
				Brownish Dense	20.00	15	20	30	50				q				Γ	D ense		SS
22	.00			Silty Fine to Medium Coarse Sand	22.00	16	21	30	51				q				V.	Dens	e	SS
		 			23.50	18	21	32	53				0				V.	Dens	e	SS
				Greyish Very Dense Silty Fine Sand	25.00	18	22	32	54				d				V.	Dens	e	SS
		 			26.50	19	24	33	57								V.	Dens	ie	SS
					28.00	20	26	35	61					$\left\langle \right\rangle$			V.	Dens	e	SS
30	.00				29.50	21	30	37	67					l			V.	Dens	e	SS

Bore Hole Terminated at a depth of 30.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.33 (10-11) Location**

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-33 (10-11) Location																											
р							lay								Sieve Analysis			Triaxial		Box Shear		(kPa)					
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	Id	$Consistency, I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L-4.50	11	SS	Sandy Clayey Silt	15	-	-	1	-	2.7	-	15	-	-	Loose	0	0	0	14	63	23	13.8	29.6	-	1	-	-	SM
4.50-12.50	22	SS	Silty Sand	11	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	84	16	0	-	-	-	-	-	-	SM
12.50-22.00	45	SS	Silty Sand	7	-	-	-	-	2.7	-	19	-	-	Dense	0	0	20	60	20	0	-	-	-	-	-	-	SM
22.00-30.00	55	SS	Silty Sand	6	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM.33 (10-11)												
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)								
BH-01	6.00	7.86	50.87	45.86								

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

4.50m

11

Loose

30.30 Deg.

* Layer-2 (from 4.50m to 12.50m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 8.00m SPT of the layer 22

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 33.60 Deg.

* Layer-3 (from 12.50m to 22.00m depth below)

Type of Strata Silty Fine to Medium

Coarse Sand Brownish

ColourBrownishThickness of Layer9.50mSPT of the layer45Relative DensityDenseAngle of Shearing Resistance, φ39.875 Deg.

* Layer-4 (from 22.00m to 30.00m depth below)

Type of Strata Silty Fine Sand

ColourGreyishThickness of Layer8.00mSPT of the layer55

Relative Density Very Dense Angle of Shearing Resistance, φ 41.75 Deg.

The ground water table was encountered at a depth of 5.00m within the explored depth of investigation in the third week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level.

Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No.	Diameter of	Safe Load	Safe Pull Out	Safe Lateral
	Pile	Carrying	carrying	Load
	(mm)	Capacity	Capacity	carrying
		(kN)	(kN)	Capacity
				(kN)
1	1000	12000	6018	600

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
- **3.** The bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level. Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
- 4. The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 33/10-11 (KHURJA - HAFIZPUR SECTION)

${\bf DESIGN\ OF\ PILE\ FOUNDATION} (Refer: BH-01)$

Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile

Bored Cast in Situ

1.1 Geometrical Data

Assumed Diameter of pile(D):

Assumed R.L of E.G.L:

Length of pile below E.G.L.(l):

R.L. of Bot. of Pile

1000.0 mm

0.000 m

30.000 m

-30.000 m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1 Layer-I Type of Strata: Sandy C Average SPT of the strata,N: 12	Clayey Silt
Bulk Density of the strata,γ: 15	kN/m^3
Angle of Shearing Resistance,φ: 30.6	Deg.
Depth of top of Strata: 0.00	m
Depth of bottom of Strata: 4.50	m
Average Thickness of Strata, I _c : 4.50	m
Effective overburden pressure over the top of strata, σ_{top} : 0.00	kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom} : 22.50	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle} : 11.25	kN/m^2
Coeff. Of Earth Pressure,k: 1.00	
Skin Resistance of the pile,q _s : 94.06	kN

1.2.1.2 Layer-II

Type of Strata: Silty Sand

Average SPT of the strata, N: 22

 $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$

Bulk Density of the strata,γ: 17 kN/m³
Angle of Shearing Resistance,φ: 33.6 Deg.
Depth of top of Strata: 4.50 m
Depth of bottom of Strata: 12.50 m
Average Thickness of Strata,I_c: 8.00 m

Effective overburden pressure over the top of strata, σ_{top} : 22.50 kN/m²

Effective overburden pressure over the bottom of strata, σ_{bottom} : 78.50 kN/m²

Effective overburden pressure at the middle of the strata, σ_{middle} : 50.50 kN/m²

Coeff. Of Earth Pressure,k: 1.50

Skin Resistance of the pile,q_s: 1264.9 kN

 $(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$

1.2.1.3 Layer-III

Type of Strata: Silty Sand

Average SPT of the strata, N: 45

	Bulk Density of the strata,γ:	19	kN/m^3
	Angle of Shearing Resistance, 6:	39.875	Deg.
	Depth of top of Strata:	12.50	m
	Depth of bottom of Strata:	22.00	m
	Average Thickness of Strata,I _c :	9.50	m
	Effective overburden pressure over the top of strata, σ_{top} :	78.50	kN/m ²
	Effective overburden pressure over the bottom of strata, σ_{bottom} :	164.00	kN/m ²
	Effective overburden pressure at the middle of the strata, σ_{middle} :	121.25	kN/m ²
	Coeff. Of Earth Pressure,k:	1.50	
	Skin Resistance of the pile,q _s :	4534.6	kN
	$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$		
1.2.1.4	Layer-IV		
	Type of Strata:	Silty Sand	
	Average SPT of the strata, N:	•	
	Bulk Density of the strata,γ:	20	kN/m^3
	Angle of Shearing Resistance, •	41.75	Deg.
	Depth of top of Strata:	22.00	m
	Depth of bottom of Strata:		m
	Average Thickness of Strata,I _c :	8.00	m
	Effective overburden pressure over the top of strata, σ_{top} :	164.00	kN/m ²
	Effective overburden pressure over the bottom of strata, σ_{bottom} :	244.00	kN/m ²
	Effective overburden pressure at the middle of the strata, σ_{middle} :	204.00	kN/m^2
	Coeff. Of Earth Pressure,k:	2.00	
	Skin Resistance of the pile,q _s :	9152.2	kN
	$(q_s:\sigma^*k^*tan\phi^*pi()^*d^*Ic)$		
	Ultimate Skin Resistance,qs:	15045.7	kN
1.2.2	Computation of End Bearing Resistance:		
	Type of Bearing Strata	Silty Sand	
	Cross-Sectional Area of pile, Ap:	0.785	m^2
	R.L of bottom of pile:	-30.00	
	Minimum SPT-value of the Bearing Strata		
	Angle of Shearing Resistance(ASR)		Degrees
	Bearing Capacity Factor(Nq)		1.0
	Effective Over Burden Pressure at the bottom of pile (q)	100.00	kPa
	(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the		
	N.G.L.)		
	Ultimate End Bearing Resistance (Qp)	17278.8	kN
	(Qp=Ap*q*Nq)		
1.3.0	Ultimate Load Carrying Capacity (Qu=Qp+q _p)	32324.4	kN
	Safe Load Carrying Capacity (Qsafe = $Qu/2.5$)		kN
	However, limit Q_{safe} to the structural capacity of pile:		kN
	, court		

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 16/05/2008; Ended On: 17/05/2008 G.W.T: 10.50m

	artc	u O	11 . 10/	15/2008; Ended On: 1//					10.5									
					SP'	Γ - D	etail	S	irapi	nica	l Re	pres	ent	atio	n o	fSP	, y	
									##	10	20	3(4	(5)	6(7	7(8	90	enc	
Denth of Ton of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
					1.50	3	5	6	11	9							Loose	SS
				Brownish Loose Sandy Clayey Silt	3.00	UDS	Colle	cted									Loose	SS
				Sandy Chrycy Shi	4.50	5	5	6	11	a							Loose	SS
					6.00	4	7	8	15								M.Dense	SS
	7.50		Н		7.50	5	9	10	19								M.Dense	SS
				Greyish to Brownish	9.00	9	12	13	25								M.Dense	SS
G	W.T	<u>↓</u>		Medium Dense Silty Fine Sand	10.50	10	12	15	27		d						M.Dense	SS
1	2.00	<u> </u>			12.00	10	13	16	29		(M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at Bridge No.35/3 Location**

		Ta	ble 2.1: Labo	ratory	Tes	t R	esu	lts o	n th	e So	il S	amp	les	Collecte	ed fi	rom	KN	1. 3:	5/3	Loca	atior	ì					
pu				-		C	lay					_				Sie	ve A	analy	sis			axial est	Box	Shear	(kPa)		
R.L. of Sample below Existing Groulevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	Id	Consistency, ${ m I_C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-7.50	12	DS	Sandy Clayey Silt	13	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	21	70	9	-	-	15.6	29.8	-	-	SM
7.50-12.00	24	SS	Silty Sand	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	84	16	0	-	-	-	-	-	-	SM

Table 2.2: Cl Water Sampl		•	esults conduc re Hole at KN	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.88	124.54	111.32

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at KM- 35/3 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)

Type of Strata Sandy Clayey Silt Colour Brownish Thickness of Layer 7.50m SPT of the layer 12 Relative Density Loose Angle of Shearing Resistance, ϕ 30.60 Deg.

* Layer-2 (from 7.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 4.50m SPT of the layer 24

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 34.20 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the

sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	12	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 35/3 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 11

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.30 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 19.29$

 $N_{v} = 23.94$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 340.59 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 136.24 kPa

Limited to an allowable bearing pressure per running meter width: 120.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 11 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 20/05/2008; Ended On: 21/05/2008 G.W.T: 9.00m

-51	ui te	4 0	11 . 20/0	13/2008, Ellueu Oll . 21				7 . 1 .	9.00	111			_
					SP'	Τ - D	etail	S	rapl	nical Repre	sentation of SP	ý	
									##	10 20 30 4	4(5) 6(7(8) 90	oue	
Depth of Top of	Layer(m)	G.W.T.(m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			Relative Density/Consistency	Type of Sample
					1.50	6	10	11	21	9		M.Dense	SS
					3.00	UDS	Samp	ler Ins	talled			M.Dense	UDS
				Brownish Medium Dense	4.50	6	10	13	23	o		M.Dense	SS
				Silty Fine Sand	6.00	7	11	14	25	o		M.Dense	SS
					7.50	8	11	15	26	o.		M.Dense	SS
G.	W.T	<u>¥.</u>			9.00	10	13	16	29			M.Dense	SS
					10.50	10	14	16	30	o		M.Dense	SS
12	.00				12.00	12	15	17	32			Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-36 Location**

		Table	2.1: Laborator	ry Test	Re	sult	s on	the	e So	il S	am	oles	Co	llected f	froi	m K	M.,	36 I	oca	tio	n						
																						axial		ox	'a)		
pq					- 11	Cla	ay									Sie	ve A	nal	ysis	ír –	T	est	Sh	ear	(kPa)		
R.L of Sample below Existing Groulevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)		Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-12.00	26	SS	Silty Sand	9	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	79	21	0	-	-	12.5	33.9	-	-	SM
				_																							

		•	ults conducted e Hole at KM.	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.83	80.98	100.82

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 12.00m
SPT of the layer 26

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.80 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	24	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 36 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 21

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 33.30 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

kPa

Effective Overburden pressure at foundation level (q) 14.00

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 28.23$

 $N_{v} = 39.32$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 680.95 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 272.38 kPa

Limited to an allowable bearing pressure per running meter width: 240.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 21 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 20/05/2008; Ended On: 21/05/2008 G.W.T: 9.00m

υı	artc	u O	11 . 20/	15/2008; Ended On: 21/					9.00				
					SP	Τ - D	etail	S	rapl	nical Rep	resentation of SP	<u>\$</u>	
									##	10 203	(4(5)6(7(8)90	oue	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			Relative Density/Consistency	Type of Sample
					1.50	5	10	12	22	q		M.Dense	SS
				Brownish Medium Dense Sandy Clayey Silt	3.00	UDS	Samp	ler Ins	talled			M.Dense	UDS
				Sality Clayey Sitt	4.50	6	10	14	24			M.Dense	SS
					6.00	8	12	15	27			M.Dense	SS
					7.50	10	13	16	29	d		M.Dense	SS
9	.00	¥			9.00	11	13	18	31		d	Dense	SS
		 		Greyish to Brownish Dense Silty Fine Sand	10.50	11	14	20	34		d	Dense	SS
12	.00	<u> </u>			12.00	12	14	22	36		J	Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-37 Location**

		Ta	ble 2.1: Labo	ratory [Test	t Re	esul	ts o	n the	e Soi	l Sa	ampl	es	Collecte	d fi	om	KN	I. 37	7 Lo	cati	ion						
nd						С	lay					_				Sie	eve A	naly	sis		l	est	Bo Sho		(kPa)		
R.L of Sample below Existing Groulevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-9.00	26	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	24	59	17	18.7	34.1	-	-	-	-	SM
									2.11		10																
9.00-12.00	32	SS	Silty Sand	8	-	-	-	-	2.66	-	18	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 37											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)							
BH-01	9.00	7.85	89.54	70.93							

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata

Colour

Brownish
Thickness of Layer

SPT of the layer

Sandy Clayey Silt

Brownish

9.00m

26

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.80 Deg.

* Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 3.00m SPT of the layer 32 Relative Density Dense Angle of Shearing Resistance, ϕ 36.55 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic					
	Foundation	Minimum	Capacity	Settlements					
	Structure	Depth of	(t/m^2)	(mm)					
		Footing below							
		N.G.L							
		(m)							
1	Isolated	2.00	24	48					
	Column								
	Footing/Raft								

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 37 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 2.00 m m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 22

Type of Shear Failure: General

Angle of Shearing Resistance, ϕ : 33.60 Deg.

1 Design Parameters:

kN/m³ Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00

Effective Overburden pressure at foundation level (q) 14.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 29.13$

 $N_{\nu} = 40.85$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 703.76 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 281.50 kPa

Limited to an allowable bearing pressure per running meter width: 240.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 22 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja, Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$

Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At KM-38

12.00

Started On: 24/05/2008; Ended On: 25/05/2008 G.W.T: 7.00m raphical Representation of SP SPT - Details Density/Consistency 10 21 31 41 51 61 71 81 90 ## Depth of Top of Type of Sample Soil Profile **Engineering Description** Layer(m) 5-30 cm 30-45 cm Relative N-Value 0-15 cm ofSoil (E) 1.50 10 12 22 M.Dense SS M.Dense UDS 3.00 UDS Sampler Installed Brownish Medium Dense Sandy Clayey Silt M.Dense 4.50 12 13 25 SS 6.00 6.00 10 15 16 31 Dense SS G.W.T 7.50 11 15 18 33 Dense SS Greyish to Brownish Dense SS Dense 9.00 12 17 19 36 Silty Fine Sand Dense 10.50 20 40 SS14 20

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-38 Location**

Dense

SS

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 38 Location																										
pun						C	lay									Sie	eve A	nal	ysis			axial est		ox ear	і (кРа)		
R.L. of Sample below Existing Grolevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	♦ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-6.00	24	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	21	61	18	15.9	33.7	-	-	-	-	SM
6.00-12.00	35	SS	Silty Sand	7	-	-	-	-	2.66	-	18	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 38											
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нd	Chlorides(ppm)	Sulphates (ppm)							
BH-01	7.50	7.88	80.92	73.41							

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata

Colour

Brownish
Thickness of Layer

SPT of the layer

Sandy Clayey Silt

Brownish

6.00m

24

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.20 Deg.

* Layer-2 (from 6.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 6.00m
SPT of the layer 35
Relative Density Dense
Angle of Shearing Resistance, φ 37.375 Deg.

The ground water table was encountered at a depth of 7.00m within the explored depth of investigation in the fourth week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic				
	Foundation	Minimum	Capacity	Settlements				
	Structure	Depth of	(t/m^2)	(mm)				
		Footing below						
		N.G.L						
		(m)						
1	Isolated	2.00	24	48				
	Column							
	Footing/Raft							

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 38 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 22

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 33.60 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 14.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 29.13$

 $N_{\nu} = 40.85$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 703.76 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 281.50 kPa

Limited to an allowable bearing pressure per running meter width: 240.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 22 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja, Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$

Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At KM-39

12.00

Started On: 24/05/2008; Ended On: 25/05/2008 G.W.T: 9.50m raphical Representation of SP SPT - Details Density/Consistency 10 21 31 41 51 61 71 81 90 ## Depth of Top of Type of Sample Soil Profile **Engineering Description** Layer(m) 5-30 cm 30-45 cm Relative N-Value 0-15 cm ofSoil (E) 1.50 10 19 M.Dense SS M.Dense UDS 3.00 UDS Sampler Installed Brownish Medium Dense Sandy Clayey Silt M.Dense 4.50 10 12 22 SS 6.00 8 11 14 25 M.Dense SS 7.50 12 15 27 M.Dense SS M.Dense 9.00 SS 10 14 15 29 9.50 Dense Greyish to Brownish 10.50 17 SS12 16 33 Dense Silty Fine Sand

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Dense

SS

Fig. 2.1 Soil Profile at KM-39 Location

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 39 Location																										
pu						C	lay									Sie	ve A	nal	ysis			axial est	Sh	ox ear	(kPa)		
R.L of Sample below Existing Groulevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	♦ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
										-																	
E.G.L-9.50	24	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	24	64	12	16.7	33.8	-	-	-	-	SM
0.50.12.00	22	SS	Cilty Cond	8					2.66		18			Danga	0	0	0	77	22	0							CM
9.50-12.00	33	33	Silty Sand	8	-	-	1	-	2.66	-	18	-	-	Dense	0	0	0	//	23	U	-	-	-	_	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 39										
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)						
BH-01	10.50	7.80	132.22	143.31						

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.50m depth below)

Type of Strata Sandy Clayey Silt
Colour Brownish
Thickness of Layer 9.50m
SPT of the layer 24

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.20 Deg.

* Layer-2 (from 9.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 1.50m
SPT of the layer 33
Relative Density Dense
Angle of Shearing Resistance, φ 36.825 Deg.

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the fourth week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	22	46
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 39 (KHURJA - HAFIZPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 19

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 32.70 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 14.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 26.45$

 $N_{v} = 36.24$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 635.34 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

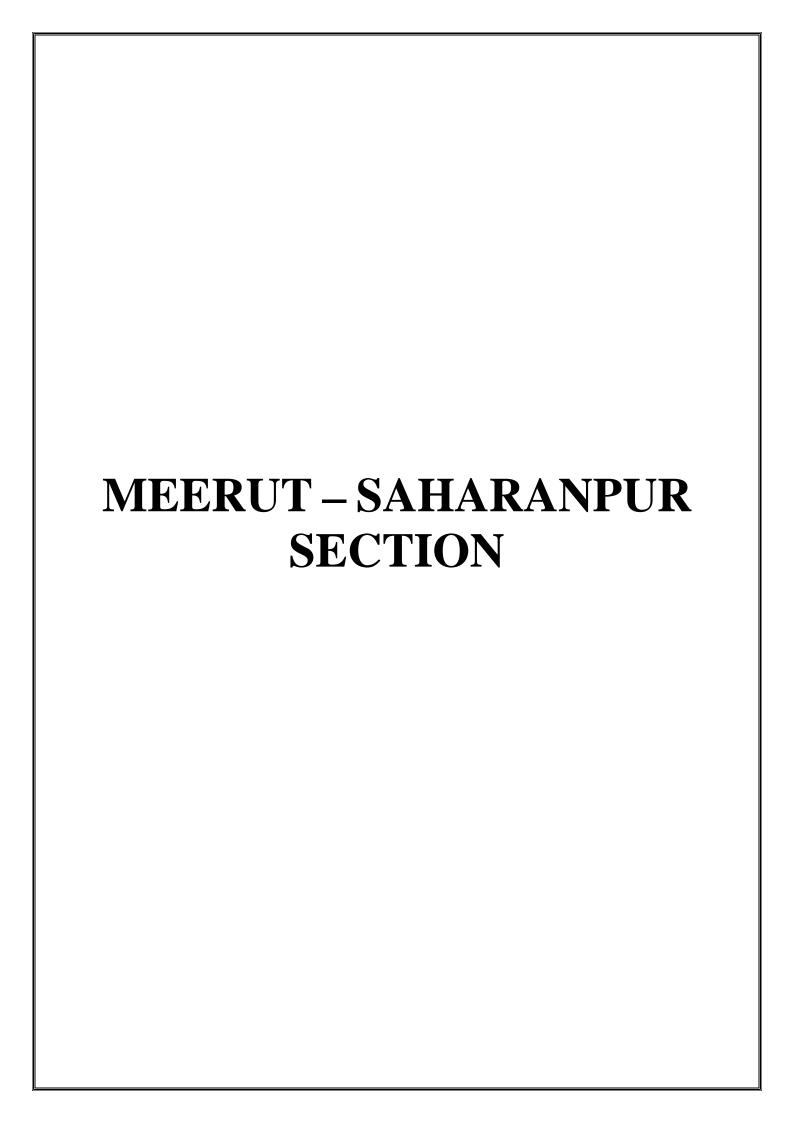
Factor of Safety (F.S.): 2.50

Qsafe: 254.14 kPa

Limited to an allowable bearing pressure per running meter width: 220.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 19 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.



Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 02/06/2008: Ended On: 02/06/2008 G.W.T: 3.00m

Sta	ırte	<u>d O</u>	n: 02/0	06/2008; Ended On: 02/	06/200)8	G.\		3.00												
					SP	Γ - D	etail	S	rapl	nica	ıl R	lep	res	en	tat	io	n c	fS	P	У.	
									##	1	0 2	213	(4	(5	16	(7	(8	19	0	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value											Relative Density/Consistency	Type of Sample
					1.50	8	13	15	28			9								M.Dense	SS
G.V	V.T	<u>+</u>		Greyish Medium Dense Silty Fine Sand	3.00	10	12	16	28			0								M.Dense	SS
		 			4.50	10	11	13	24		•	{								M.Dense	SS
6.	00	} }	Ш		6.00	13	17	17	34			,								Dense	SS
		 			7.50	9	14	20	34				o							Dense	SS
				Greyish Dense	9.00	8	15	18	33			,								Dense	SS
		 		Silty Fine Sand	10.50	10	17	26	43					\						Dense	SS
12	.00				12.00	16	23	31	54					,	Ì					V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.85 Location**

		Tab	le 2.1: Labor	atory	Tes	t R	esu	lts o	on th	ne S	oil	Sam	ple	s Collec	cted	fro	m I	KM-	-85	Loc	atio	1					
pu						C	lay									Sie	eve A	naly	ysis			xial est	Box	Shear	(kPa)		
R.L of Sample below Existing Groulevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-6.00	27	SS	Silty Sand	10	_	-	_	_	2.67	0.27	17	-	-	M.Dense	0	0	0	79	21	0	_	_	16.7	34.6	_	_	SM
			-																								
6.00-12.00	36	SS	Silty Sand	7	-	-	-	-	2.65	0.19	18	-	-	Dense	0	0	0	73	27	0	-	-	-	-	-	-	SM

Table 2.2: Cl Water Samp		•	esults conduc ore Hole at K	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	3.00	7.81	90.88	65.56

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 6.00m
SPT of the layer 27

Relative Density Medium Dense

Angle of Shearing Resistance 35.10°

* Layer-2 (from 6.00m to 12.00m depth below)

Type of Strata Silty Fine Sand

ColourGreyishThickness of Layer6.00mSPT of the layer36Relative DensityDenseAngle of Shearing Resistance37.65°

The ground water table was encountered at a depth of 3.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	30	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 85 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 2.00 m m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 28

Type of Shear Failure: General

Angle of Shearing Resistance, ϕ : 35.40 Deg.

1 Design Parameters:

kN/m³ Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00

Effective Overburden pressure at foundation level (q) 14.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 35.77$

 $N_{v} = 52.94$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 876.05 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 350.42 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 28 are computed to be in the order of 48mm which is within the permissible limits of

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC. Started On: 03/06/2008; Ended On: 03/06/2008 G.W.T: 7.50m

2	arte	ea O	n: 0.3/0	06/2008; Ended On: 03/	00/200	J8	<u>ن. ب</u>	<u>v.i:</u>	7.50	m						
					SP'	Τ - D	etail	S	rapl	nical	Represe	ntati	on o	fSP	<u></u>	
									##	10	203040	5160	7(8	190	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value						Relative Density/Consistency	Type of Sample
2	2.00			Brownish Loose Sandy Clayey Silt	1.50	4	6	6	12	٩	\				Loose	SS
					3.00	8	12	17	29		9				M.Dense	SS
				Greyish to Brownish Medium Dense Silty Fine Sand	4.50	6	10	16	26		d				M.Dense	SS
				Sity File Sand	6.00	12	12	16	28		d				M.Dense	SS
	.50	\	#		7.50	8	15	17	32		d				Dense	SS
				Greyish Dense Silty Fine Sand	9.00	11	17	20	37						Dense	SS
1	0.50		Ш	0.11	10.50	18	24	33	57			4			V.Dense	SS
				Greyish Very Dense								\				
1	2.00	<u> </u>		Silty Fine Sand	12.00	20	28	39	67			}	١		V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.86 Location**

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-86 Location Clay Sieve Analysis Triaxial Trest Box Shear Of the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from KM-86 Location Sieve Analysis To the Soil Samples Collected from																										
g						C	lay									Sie	eve A	\nal	ysis				Box	Shear	kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	ф (Deg.)	Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-2.00	12	SS	Sandy Clayey Silt	10	-	-	-	-	2.68	0.27	15	-	-	Loose	0	0	0	21	65	14	-	-	15.4	29.9	-	-	SM
2.00-7.50	28	SS	Silty Sand	9	-	-	-	-	2.67	0.24	17	-	-	M.Dense	0	0	0	85	15	0	-	-	-	-	-	-	SM
7.50-10.50	34	SS	Silty Sand	8	-	-	-	-	2.66	0.21	18	-	-	Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
			Ţ.																								
10.50-12.00	57	SS	Silty Sand	6	-	-	-	-	2.65	0.16	20	-	-	V.Dense	0	0	0	74	16	10	-	-	-		-	-	SM

		-	esults conduc ore Hole at F	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.79	111.23	78.55

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 2.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Sandy Clayey Silt

Brownish

2.00m

12

Loose

30.60°

* Layer-2 (from 2.00m to 7.50m depth below)

Type of Strata Silty Fine Sand
Colour Greyish to Brownish

Thickness of Layer 5.50m SPT of the layer 28

Relative Density Medium Dense

Angle of Shearing Resistance 35.40°

* Layer-3 (from 7.50m to 10.50m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Silty Fine Sand

Greyish

3.00m

SPT of the layer

Dense

37.10°

* Layer-4 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 1.50m

SPT of the layer 57

Relative Density Very Dense Angle of Shearing Resistance 42.05°

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	30	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 86 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 29

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 35.70 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 14.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 37.63$

 $N_{v} = 56.62$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 925.44 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 370.18 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 29 are computed to be in the order of 48mm which is within the permissible limits of

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 03/06/2008; Ended On: 03/06/2008 G.W.T: 8.00m

Starte	J O	n : 03/00	b/2008; Ended On: 03/06.				1:8.0					
				SP	Γ - D	etail	s	G	raphic	cal Representation of SPT	_	
								0	10	20 30 40 50 60 70 80 90	ncs	
Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			Relative Density/Consistency	Type of Sample
2.00			Brownish to Greyish Loose Sandy Clayey Silt	1.50	5	6	7	13	٩		Loose	SS
	•			3.00	13	15	19	34			Dense	SS
				4.50	18	20	22	42			Dense	SS
			Greyish Dense Silty Fine Sand	6.00	20	23	24	47		0	Dense	SS
G.W.T	¥			7.50	22	24	24	48			Dense	SS
9.00				9.00	25	25	26	51		d	V.Dense	SS
			Greyish Very Dense Silty Fine Sand	10.50	24	27	39	66			V.Dense	SS
12.00	<u> </u>			12.00	28	30	31	61		d	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.89 Location

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-89 Location Clay																										
pı						C	lay							_		Sie	eve A	naly	ysis				Box	Shear	kPa)		
R.L of Sample below Existing Ground level(m)		\mathbf{v}	Engineering Classification of	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	-	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Pressure	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	ф (Deg.)	Tests, Cu		IS-Classification
E.G.L-2.00	13	SS	Sandy Clayey Silt	12	-	1	-	-	2.68	0.32	15	-	-	Loose	0	0	0	24	67	9	-	-	-	-	-	-	SM
2.00-9.00	43	SS	Silty Sand	8	-	-	-	-	2.67	0.21	19	-	-	Dense	0	0	0	81	19	0	-	-	14.5	38.7	-	-	SM
10.50-12.00	59	SS	Silty Sand	7	_	-	_	_	2.65	0.19	20	_	-	V.Dense	0	0	0	78	22	0	_	-	-	-	-	-	SM
			Ĭ																								

	d on W	ater Sa	Analysis Res ample collecte t KM.89	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.85	88.65	70.79

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

k Layer-1 (from E.G.L to 2.00m depth below)

Type of Strata Sandy Clayey Silt
Colour Brownish to Greyish

Thickness of Layer 2.00m
SPT of the layer 13
Relative Density Loose
Angle of Shearing Resistance 30.90°

Layer-2 (from 2.00m to 9.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 7.00m
SPT of the layer 43
Relative Density Dense
Angle of Shearing Resistance 39.425°

* Layer-3 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 3.00m
SPT of the layer 59

Relative Density Very Dense Angle of Shearing Resistance 42.35°

The ground water table was encountered at a depth of 8.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	33	46
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 89 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m
Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 34

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 37.10 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 18.00 kN/m³

Effective Overburden pressure at foundation level (q) 16.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 46.28$

 $N_{\nu} = 73.81$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 1294.73 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 517.89 kPa

Limited to an allowable bearing pressure per running meter width: 330.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 330kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 330kPa and SPT of 34 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC. Started On: 04/06/2008; Ended On: 04/06/2008 G.W.T: 8.00m

Sta	110	u O	11 . 0 - 7/1	00/2008, Elided Oll . 0	1 /00/20	700		. ** .	1.0	IIIOO			
					SPT	Γ - D	etai	ls	Gra	phica	al Representation of SPT		
									0	10	20 30 40 50 60 70 80 90	ncy	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			Relative Density/Consistency	Type of Sample
				Brownish to Yellowish	1.50	9	17	19	36		Ĵ	Dense	SS
	Dense Sandy Clayey S		Dense Sandy Clayey Silt	3.00	12	14	14	28			M. Dense	SS	
4.	50	Ц			4.50	10	17	21	38		}	Dense	SS
					6.00	12	20	21	41			Dense	SS
				Greyish Dense	7.50	17	21	23	44			Dense	SS
G.V	G.W.T <u>▼</u>	9.00	20	20	23	43			Dense	SS			
					10.50	20	21	26	47			Dense	SS
12.	.00	┟╌┨			12.00	22	24	32	56		Ì	V. Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at KM.90 Location

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-90 Location																										
nd						C	lay									Sie	eve A	naly	ysis			axial est	Box	Shear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	PT (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-4.50	32	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	0.29	18	-	-	Dense	0	0	0	23	56	21	-	-	18.7	36.0	-	-	SM
4.50-12.00	43	SS	Silty Sand	7	-	_	-	-	2.66	0.19	19	_	_	Dense	0	0	0	78	22	0	-	-	-	_	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.03										
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)						
BH-01	12.00	7.89	88.34	79.56						

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Sandy Clayey Silt

Brownish

4.50m

32

Dense

36.55°

* Layer-2 (from 4.50m to 12.00m depth below)

Type of Strata Silty Fine Sand

ColourGreyishThickness of Layer7.50mSPT of the layer43Relative DensityDenseAngle of Shearing Resistance39.425°

The ground water table was encountered at a depth of 8.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	30	45
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of sandy clayey silt
 and can be considered as bearing strata for the proposed impending loads from
 the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 90 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 28

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 35.40 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 14.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 35.77$

 $N_{v} = 52.94$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_{u} = 876.05 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

 $Qsafe: \hspace{0.5cm} 350.42 \hspace{0.2cm} kPa$

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 28 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 05/06/2008: Ended On: 05/06/2008 G.W.T: 8.00m

Sta	arte	u O	II . U3/C	06/2008; Ended On: 05/	00/200	70	U.1	V . I :	8.00	/111		
					SP	Γ - D	etail	S	iraph	nical Representation of SP	8	
									##	10 2(3(4(5)6(7(8)90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
				Brownish Dense	1.50	8	15	20	35	9	Dense	SS
	50	•		Sandy Clayey Silt	3.00	UDS 10	Colle	cted	35		Dense Dense	SS
4.	30				6.00	12	16	22	38	0	Dense	SS
G.V	V.T	<u></u>		Greyish Dense	7.50	10	17	20	37	4	Dense	SS
				Silty Fine Sand	9.00	15	22	24	46		Dense	SS
10	.50			Greyish Very Dense	10.50	20	24	27	51	4	V.Dense	SS
12	.00			Silty Fine Sand	12.00	22	28	32	60)	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.91 Location**

			Table 2.1: La	abora	tor	y T	est	Res	sults	on t	the S	oil S	am	ples Co	llec	cted	fro	m I	KM.	91	Loc	atioı	1				
pu						Cl	lay									Sie	ve A	\nal _\	ysis			ixial est		ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	${\color{red}Consistency, I_C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-4.50	35	SS	Sandy Clayey Silt	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	16	60	24	-	-	16.7	37.1	-	-	SM
4.50-10.50	39	SS	Silty Sand	7					2.7		19			Dense	0	0	0	78	18	4							SM
4.30-10.30	39	33	Siny Sand	/	-	-	-	-	2.7	-	19	-	-	Dense	U	U	0	78	18	4	-	-		-	-	-	SIVI
10.50-12.00	51	SS	Silty Sand	5	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	72	28	0	-	-	-	-	-	-	SM

conduct	ed on	Water	Analysis Res Sample collect at KM. 91	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.88	70.23	65.67

SUB-SURFACE STRATIFICATION

3.0 **Preamble**

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of **Shearing Resistance.**
- For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate **Unconfined Compressive Strength.**

3.1 **Sub Surface Stratification:**

Soil Profile at BH-01 Location 3.1.1

(As presented in the site plan)

Laver-1 (from E.G.L to 4.50m depth below)

Type of Strata Sandy Clayey Silt Colour Brownish Thickness of Layer 4.50m SPT of the layer 35 Relative Density Dense Angle of Shearing Resistance, ϕ 37.375 Deg.

Layer-2 (from 4.50m to 10.50m depth below)

Type of Strata Silty Fine Sand Colour Greyish 6.00m Thickness of Layer SPT of the layer 39 Relative Density Dense Angle of Shearing Resistance, ♦ 38.475 Deg.

Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Greyish Colour Thickness of Layer 1.50m SPT of the layer 51 Relative Density Very Dense

Angle of Shearing Resistance, ϕ 41.15 Deg.

The ground water table was encountered at a depth of 8.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	30	45
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 91 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 n

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 35

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 37.38 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 18.00 kN/m³

Effective Overburden pressure at foundation level (q) 12.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 47.98$

 $N_{\gamma} = 77.19$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 1095.78 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 438.31 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 35 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 04/06/2008; Ended On: 04/06/2008 G.W.T: 7.50m

שני	utec	ı O	11.04/1	06/2008; Ended On: 04/	00/200	70	U.1	W . I .	7.50	111				
					SP'	T - D	etail	.S	rapl	nical I	Representation	ofSP	ý	
									##	10 2	213(4(5)6(7(8190	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value				Relative Density/Consistency	Type of Sample
2.	00			Filled Up Soil	1.50	SPT	not co	nduc	ted for	the fill	l layer		-	DS
	•	•		Yellowish Medium Dense	3.00	8	9	11	20	9			M.Dense	SS
				Sandy Clayey Silt	4.50	11	13	15	28				M.Dense	SS
6.	00			0.11	6.00	18	21	22	43		Ì		Dense	SS
7.	50	ţ		Greyish Dense Silty Fine Sand	7.50	21	24	27	51				V.Dense	SS
				Greyish	9.00	22	26	25	51		•		V.Dense	SS
				Very Dense Silty Fine Sand	10.50	22	25	27	52				V.Dense	SS
12	.00	<u> </u>			12.00	27	31	32	63				V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.92 Location**

		7	Table 2.1: Lal	borat	ory	у Т	est]	Res	ults	on t	he S	oil S	San	nples C	olle	cted	l fro	om	KM	[, 92	2 Lo	catio	n				
pu						C	lay	1								Sie	ve A	naly	ysis			est		ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $ m I_{C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
EGI 200		D.C.	Ell III C l																								
E.G.L-2.00	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.00-6.00	24	SS	Sandy Clayey Silt	11	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	21	55	24	-	-	18.4	33.7	-	-	SM
6.00-7.50	43	SS	Silty Sand	6	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM
7.50-12.00	51	SS	Silty Sand	5	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

conduct	ed on	Water	Analysis Res Sample colle at KM. 92	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.86	98.65	77.54

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 2.00m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 2.00m SPT of the layer -

Layer-2 (from 2.00m to 6.00m depth below)

Type of Strata Sandy Clayey Silt

Colour Yellowish
Thickness of Layer 4.00m
SPT of the layer 24

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.20 Deg.

* Layer-3 (from 6.00m to 7.50m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 43
Relative Density Dense
Angle of Shearing Resistance, φ 39.425 Deg.

* Layer-4 (from 7.50m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 51

Relative Density Very Dense Angle of Shearing Resistance, φ 41.15 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the top filled up soil strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level i.e. 3.50m from the existing ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	20	44
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the top filled up soil strata are coarse-grained type in the form of sandy clayer silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level or 3.50m below the existing ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 92 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 3.50 n

Observed Maximum thickness of Filled up Soil: 2.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 20

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 33.00 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 27.34$

 $N_{\nu} = 37.78$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_{\rm u} = 533.75 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 213.50 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 20 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 05/06/2008: Ended On: 05/06/2008 G.W.T: 7.50m

St	arte	a O	n : 05/C	06/2008; Ended On: 05/	06/200	78	G.1	<i>N</i> .1:	7.50)m		
					SP	Γ - D	etail	S	rapl	hical Representation of SF	y	
									##	10 21 31 41 51 61 71 81 90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
				Brownish								
				Medium Dense								
				Sandy Clayey Silt	1.50	12	13	15	28	٩	M.Dense	SS
2	.00											
		•			3.00	13	15	17	32	1	Dense	SS
					4.50	15	18	20	38	}	Dense	SS
				Brownish Dense Silty Fine Sand	6.00	15	17	21	38		Dense	SS
G.	w.T	<u>↓</u> .			7.50	17	20	27	47	•	Dense	SS
					9.00	18	21	21	42	4	Dense	SS
10).50			Greyish	10.50	17	22	31	53		V.Dense	SS
				Very Dense						\		
12	2.00			Silty Fine Sand	12.00	28	30	32	62	<i>l</i>	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.93 Location**

			Table 2.1: La	aborator	уT	'est	Re	sult	ts or	the	e So	oil S	am	ples Co	llec	ted	fro	m I	(M	. 93	Loc	atio	n				
pun						C	lay									Sie	ve A	nal	ysis			est		ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
					-																						
E.G.L-2.00	28	SS	Sandy Clayey Silt	13	-	-	-	-	2.7	-	18	-	-	M.Dense	0	0	0	24	63	13	-	-	17.8	34.9	-	-	SM
2.00.10.50	39	SS	Silty Sand	8	$\parallel \parallel$				2.7		10			Dange	0	0	0	70	21								SM
2.00-10.50	39	33	Silty Sand	8	-	-	-	-	2.1	-	19	-	-	Dense	U	U	U	79	21	0	-	-	-	-	-	-	SIVI
10.50-12.00	53	SS	Silty Sand	6	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

conduc	cted or	n Wate	ll Analysis R r Sample col le at KM. 93	lected
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.81	100.32	89.44

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 2.00m depth below)

Type of Strata Sandy Clayey Silt
Colour Brownish
Thickness of Layer 2.00m

SPT of the layer 28

Relative Density Medium Dense Angle of Shearing Resistance, φ 35.40 Deg.

* Layer-2 (from 2.00m to 10.50m depth below)

Type of Strata Silty Fine Sand Colour Brownish Thickness of Layer 8.50m SPT of the layer 39 Relative Density Dense Angle of Shearing Resistance, ϕ 38.475 Deg.

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 53

Relative Density Very Dense Angle of Shearing Resistance, φ 41.45 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	25	47
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 93 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

 $Type\ of\ Footing:\ Isolated\ Column$ Depth of foundation below the E.G.L: 1.50 $\,$ m
Observed Maximum thickness of Filled up Soil: 0.00 $\,$ m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 28

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 35.40 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 35.77$

 $N_{\gamma} = 52.94$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 713.28 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 285.31 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 28 are computed to be in the order of 47mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 05/06/2008: Ended On: 05/06/2008

_51	<u>arte</u>	<u>a O</u>	<u>n : 05</u> /0	06/2008; Ended On: 05/	<u>06/2</u> 00	J8	<u> </u>	<u>~ . 1</u> :	7.50	m						
					SPT - Details raphical Representation of SP										y.	
						## 10 203				213(4(5)6(7(8)90				enc		
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value						Relative Density/Consistency	Type of Sample
				Yellowish	1.50	6	8	17	25	q					V.Stiff	SS
		•		Very Stiff Silty Clay	3.00	8	14	14	28					V.Stiff	SS	
4	.50				4.50	9	14	18	32		d				Dense	SS
6	.00			Yellowish Dense Silty Fine Sand	6.00	13	24	27	51				V.Dense	SS		
G.	W.T	↓			7.50	15	26	28	54						V.Dense	SS
				Yellowish Very Dense Silty Fine Sand	9.00	19	22	24	46		•	/ \			Dense	SS
					10.50	18	25	28	53			1			V.Dense	SS
1	2.00				12.00	20	30	32	62						V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.94 Location**

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-94 Location																										
pu						Cl	ay									Sie	eve A	naly	sis		Triaz Tes		Be She	ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-4.50	26	SS, UDS	Silty Clay	31	75	34	41	1.1	2.66	0.82	10	67	50	V.Stiff	0	0	0	0	29	71	167.9	14.5	-	_	173.3	0.59	СН
L.U.L-4.30	20	33, 003	Sifty Clay	31	13	JŦ	71	1.1	2.00	0.02	17	07	30	V.5011	0	U		U	2)	/ 1	107.7	14.5	_	_	113.3	0.57	CII
4.50-6.00	32	SS	Silty Sand	8	-	-	-	-	2.66	0.21	18	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
6.00-12.00	51	SS	Silty Sand	5	_	-	-	_	2.65	0.13	20	-	-	V.Dense	0	0	0	72	28	0	_	-	-	-	_	-	SM
			Ĭ																								

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-94								
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)				
BH-01	7.50	7.86	100.12	78.66				

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata Silty Clay
Colour Yellowish
Thickness of Layer 4.50m
SPT of the layer 26
Consistency Very Stiff
Undrained Cohesion, Cu 173.33kPa

* Layer-2 (from 4.50m to 6.00m depth below)

Type of Strata

Colour

Yellowish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Silty Fine Sand

Yellowish

1.50m

32

Dense

36.55°

* Layer-3 (from 6.00m to 12.00m depth below)

Type of Strata

Colour

Yellowish

Thickness of Layer

SPT of the layer

Relative Density Very Dense Angle of Shearing Resistance 41.15°

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	30	45

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 94 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50

Observed Maximum thickness of Filled up Soil: $0.00\,$ m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 25

Type of Shear Failure: General

Undrained Cohesion, Cu: 166.67 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 19.00 kN/m³

Effective Overburden pressure at foundation level (q) 22.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\gamma} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\!\scriptscriptstyle \gamma} = \ N\!/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 1113.67 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 445.47 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 25 are computed to be in the order of 45mm which is within the permissible limits of 50mm for isolated column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 06/06/2008; Ended On: 06/06/2008 G.W.T: 6.00m

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					SP'	T - D	etail	S	rapl	hical Representation of SP	ý	
									##	10 21 31 41 51 61 71 81 90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
				Brownish Stiff	1.50	6	7	7	14	9	Stiff	SS
4.	.50			Silty Clay	3.00 4.50	UDS	Colle	cted	30		Stiff M.Dense	SS SS
	.00	+		Brownish Medium Dense Sandy Clayey Silt	6.00	13	17	20	37		Dense	SS
				Greyish Very Dense Silty Fine Sand	7.50	12	22	24	46		Dense	SS
9.	.00				9.00	21	26	28	54	•	V.Dense	SS
		 		Greyish Very Dense Silty Fine Sand	10.50	23	27	29	56		V.Dense	SS
12	.00	-			12.00	20	26	30	56		V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.98 Location**

			Table 2.	1: Labo	rat	ory	Tes	t R	esults o	on tl	ne Se	oil S	am	ples Co	llec	cted	fro	m I	ΚM	-98	Locat	tion					
						- CI									Sieve Analysis Test							OX	a)				
pun						C	lay									Sie	ve A	nal	ysis		Tes	st	Sh	ear	ı (kPa)		
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	Id	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, C	Consolidation Tests, Cc	IS-Classification
E.G.L-4.50	14	SS, UDS	Silty Clay	36	79	28	51	0.8	2.68	1	16	72	55	Stiff	0	0	0	0	24	76	88.5	11.2	-	-	93.3	0.62	СН
4.50.500	20	9.0	GIL G	0					2.47	0.2	10							0.1	1.0								G) (
4.50-6.00	30	SS	Silty Sand	9	-	-	-	-	2.67	0.2	18	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
6.00-9.00	42	SS	Silty Sand	7	-	-	_	-	2.65	0.2	19	_	-	Dense	0	0	0	78	22	0	-	-	-	_	_	-	SM
9.00-12.00	55	SS	Silty Sand	6	_	-	-	-	2.65	0.2	20	-	-	V.Dense	0	0	0	73	27	0	-	-	-	-	-	-	SM

conduc	ted or	wate	l Analysis Ro r Sample coll le at KM-98	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.89	78.75	66.49

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata

Colour

Brownish
Thickness of Layer

SPT of the layer

Consistency

Undrained Cohesion, Cu

Silty Clay

Brownish

4.50m

Stiff

93.33kPa

Layer-2 (from 4.50m to 6.00m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 1.50m
SPT of the layer 30

Relative Density Medium Dense

Angle of Shearing Resistance 36.00°

* Layer-3 (from 6.00m to 9.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Silty Fine Sand

Greyish

3.00m

42

Dense

39.20°

* Layer-4 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand
Colour Greyish
Thickness of Layer 3.00m
SPT of the layer 55

Relative Density Dense Angle of Shearing Resistance 41.75°

The ground water table was encountered at a depth of 6.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of rafts located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	20	66

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 98 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 14

Type of Shear Failure: General

Undrained Cohesion, Cu: 93.33 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m³

Effective Overburden pressure at foundation level (q) 15.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\gamma} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\!\scriptscriptstyle \gamma} = \ N\!/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 623.65 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 249.46 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 14 are computed to be in the order of 66mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 06/06/2008; Ended On: 06/06/2008 G.W.T: 6.00m

Sta	ILC	u O	11.00/0	16/2008; Ended On: 06/	00/200	70	U.1	W . I .	6.00				
					SP'	T - D	etail	S	rapi	nical Represent	ation of SP	>	
									##	10 20 30 40 50	6(7(8)90	enc	
Depth of Top of	Layer(m)	G.W.T.(m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			Relative Density/Consistency	Type of Sample
				Greyish Very Stiff	1.50	8	10	12	22	٩		V.Stiff	SS
4.0	00	•		Silty Clay	3.00	UDS	Colle	cted				V.Stiff	SS
6.0	00	+		Brownish Medium Dense Sandy Clayey Silt	4.50 6.00	9	11	17 19	28			M.Dense	SS SS
				Greyish	7.50	12	17	19	36	o		Dense	SS
				Dense Silty Fine Sand	9.00	12	16	20	36			Dense	SS
10.	50			Greyish Very Dense	10.50	19	27	32	59		Þ	V.Dense	SS
12.	00			Silty Fine Sand	12.00	26	27	32	59		0	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.99 Location**

				Table 2.1:	Labora	atoı	ry 🛚	Гest	Re	sults (on th	ie S	Soil	Sam	oles Co	llec	ted	fro	m K	M-	99 <u>1</u>	Locati	on					
p							C	lay									Sie	ve A	naly	ysis		Triaz Tes			ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)		SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L-4.	00	22	SS, UDS	Silty Clay	34	79	35	44	1	2.66	0.9	18	70	54	V.Stiff	0	0	0	0	25	75	140.2	15.8	_	_	146.7	0.62	СН
E.G.E 1.			55, CD5	Shity Chay	31	"	33		1	2.00	0.7	10	70	31	V.BIII	0		0		23	73	110.2	13.0			110.7	0.02	
4.00-6.0	00	28	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	0.3	17	-	-	M.Dense	0	0	0	14	66	20	-	-	-	1	-	-	SM
6.00-10.	50	35	SS	Silty Sand	7	_	_	_	_	2.66	0.2	18	_	_	Dense	0	0	0	79	21	0	-	_	_	-	_	_	SM
10.50-12	.00	59	SS	Silty Sand	5	-	-	-	-	2.65	0.1	20	-	-	V.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

	ed on '		Analysis Res nple collecte KM-99	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.88	89.87	76.53

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.00m depth below)

Type of Strata Silty Clay
Colour Yellowish
Thickness of Layer 4.50m
SPT of the layer 22
Consistency Very Stiff

Consistency Very Stiff Undrained Cohesion, Cu 146.67kPa

* Layer-2 (from 4.00m to 6.00m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 2.00m
SPT of the layer 28

Relative Density Medium Dense

Angle of Shearing Resistance 35.40°

* Layer-3 (from 6.00m to 10.50m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Silty Fine Sand

Greyish

4.50m

35

Dense

37.375°

* Layer-4 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 59

Relative Density Angle of Shearing Resistance Very Dense 42.20°

The ground water table was encountered at a depth of 6.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	30	49

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 99 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50 n

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 22

Type of Shear Failure: General

Undrained Cohesion, Cu: 146.67 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 18.00 kN/m³

Effective Overburden pressure at foundation level (q) 20.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\gamma} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\!\scriptscriptstyle \gamma} = \ N\!/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 980.03 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

 $Qsafe: \qquad 392.01 \;\; kPa$

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 22 are computed to be in the order of 49mm which is within the permissible limits of 50mm for isolated column footings as per LS:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 07/06/2008; Ended On: 07/06/2008 G.W.T: 7.50m

2	tarte	u O	n:0//C	76/2008; Ended On: 0//	00/200	10	U.1	W.I.	7.50	/111		
					SP'	T - D	etail	S	rapl	nical Representation of S	P >	
									##	10 21 3(4(5) 6(7(8) 9)	enc	
Denth of Ton of	Layer(m)	G.W.T.(m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
				Greyish	1.50	10	12	14	26	1	V.Stiff	ss
4	4.00			Very Stiff Silty Clay	3.00	UDS	Colle	cted			V.Stiff	ss
				Brownish	4.50	10	17	18	35		Dense	SS
				Dense Sandy Clayey Silt	6.00	12	15	17	32	4	Dense	ss
<u> </u>	7.50	ţ	10000		7.50	11	23	25	48		Dense	SS
				Greyish to Brownish Dense	9.00	12	21	23	44		Dense	ss
1	0.50			Silty Fine Sand Greyish	10.50	22	31	34	65	}	V.Dense	SS
1	2.00			Very Dense Silty Fine Sand	12.00	24	28	30	58		V.Dense	SS

Bore Hole Terminated at a depth of 12.00 below the existing ground level

Fig. 2.1 Soil Profile at KM.100 Location

		7	Table 2.1: Lal	borat	ory	7 Te	st R	Resu	ılts on	the	So	il S	amı	oles Co	llec	ted	fro	m I	M-	-100	Loc	catio	n				
g						C	lay								Sieve Analysis Triaxial Box Shear					(kPa)							
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E C I 400	26	GG TIPG	G'14 G1	27	7.5	22	40	1.1	2.65	0.7	10	60		27.07.00	_	0			2.4	7.0		10.7			172.2	0.50	CII
E.G.L-4.00	26	SS, UDS	Silty Clay	27	75	33	42	1.1	2.65	0.7	19	68	55	V.Stiff	0	0	0	0	24	/6	####	18.7	-	-	173.3	0.59	СН
4.00-7.50	33	SS	Sandy Clayey Silt	8	-	-	-	1	2.66	0.2	18	-	-	Dense	0	0	0	21	64	15	-	-	-	-	-	-	SM
7.50-10.50	46	SS	Silty Sand	6	-	-	-	-	2.66	0.2	19	-	-	Dense	0	0	0	78	22	0	-	-	-	1	-	-	SM
10.50-12.00	65	SS	Silty Sand	5	-	-	-	-	2.65	0.1	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

conduc	ted on	Water S	Analysis Resu Sample collect at KM-100	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.85	111.23	89.75

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.00m depth below)

Type of Strata Silty Clay
Colour Greyish
Thickness of Layer 4.00m
SPT of the layer 26
Consistency Very Stiff

Undrained Cohesion, Cu 173.33kPa

* Layer-2 (from 4.00m to 7.50m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 3.50m
SPT of the layer 33
Relative Density Dense
Angle of Shearing Resistance 36.825°

* Layer-3 (from 7.50m to 10.50m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 3.00m SPT of the layer 46 Relative Density Dense Angle of Shearing Resistance 40.10°

* Layer-4 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 1.50m
SPT of the layer 65

Relative Density Angle of Shearing Resistance Very Dense 42.50°

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	33	46

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 100 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50

Observed Maximum thickness of Filled up Soil: $0.00\,$ m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 26

Type of Shear Failure: General

Undrained Cohesion, Cu: 173.33 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 18.00 kN/m³

Effective Overburden pressure at foundation level (q) 20.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\gamma} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\!\scriptscriptstyle \gamma} = \ N\!/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 1158.21 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 463.29 kPa

Limited to an allowable bearing pressure per running meter width: 330.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 330kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 330kPa and SPT of 26 are computed to be in the order of 46mm which is within the permissible limits of 50mm for isolated column footings as per LS:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 07/06/2008: Ended On: 07/06/2008 G.W.T: 7.50m

3	arte	u O	n : 07/0	06/2008; Ended On: 07/	06/200	78	U.1	/V . I :	7.50	/111		
					SP'	Γ - D	ý					
							enc					
Depth of Top of	Layer(m)	G.W.T.(m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
					1.50	11	17	15	32	9	Dense	SS
				Brownish Dense	3.00	UDS	Colle	cted			Dense	SS
				Sandy Clayey Silt	4.50	9	12	15	27		Dense	SS
					6.00	15	17	20	37		Dense	SS
7	.50	¥			7.50	14	16	16	32		Dense	ss
9	0.00			Greyish to Brownish Dense Silty Fine Sand	9.00	21	23	28	51	4	V.Dense	SS
				Greyish Very Dense Silty Fine Sand	10.50	21	28	35	63		V.Dense	SS
1	2.00				12.00	22	27	38	65	J	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.101 Location**

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 101 Location																													
pu									Clay										Sie	ve A	nal	ysis			axial est		ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification			
E.G.L-7.50	32	SS	Sandy Clayey Silt	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	80	20	0	19.8	35.5	-	-	-	-	SM			
7.50.0.00	22		GTL G I						2.5		10																G) f			
7.50-9.00	32	SS	Silty Sand	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM			
9.00-12.00	57	SS	Silty Sand	6	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM			

conduct	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 101												
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)									
BH-01	7.50	7.80	111.12	100.46									

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Sandy Clayey Silt

Brownish

7.50m

32

Dense

36.55 Deg.

* Layer-2 (from 7.50m to 9.00m depth below)

Type of Strata

Colour

Greyish to Brownish

 $\begin{array}{ccc} \text{Thickness of Layer} & 1.50\text{m} \\ \text{SPT of the layer} & 32 \\ \text{Relative Density} & \text{Dense} \\ \text{Angle of Shearing Resistance, } \phi & 36.55 \text{ Deg.} \end{array}$

* Layer-3 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand

ColourGreyishThickness of Layer3.00mSPT of the layer57

Relative Density Very Dense Angle of Shearing Resistance, φ 42.05 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	30	45
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 101 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50

Observed Maximum thickness of Filled up Soil: $0.00\,$ m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 32

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 36.55 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 18.00 kN/m³

Effective Overburden pressure at foundation level (q) 12.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 42.88$

 $N_{\gamma} = 67.06$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_{\rm u} = 970.67 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 388.27 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 32 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 08/06/2008; Ended On: 08/06/2008 G.W.T: 7.50m

, Juli	icu	On	. 00/0	6/2008; Ended On: 08/0				V . I:	_			1
					SP	T - D	etail	S		raphical Representation of SPT		
									0	10 2030 40 50 60 70 80 9	<u>)</u> §	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
				Brownish Medium Dense Sandy Clayey Silt	1.50	9	10	11	21	1	M.Den se	SS
3.5	0				3.00	UDS	Co llecte	ed			M.Den se	ss
				Brownish	4.50	10	18	20	38		Dense	SS
				Dense Sandy Clayey Silt	6.00	13	22	23	45		Dense	SS
7.5	0	¥			7.50	16	23	27	50	}	Dense	SS
		 		Greyish Dense	9.00	22	24	26	50		Dense	ss
10.	50			Silty Fine Sand	10.50	22	30	32	62	\	V.Dense	ss
		$\left \cdot \right $		Greyish Very Dense								
12.	00			Silty Fine Sand	12.00	15	33	34	67	,	V.Den se	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.102 Location**

		T	able 2.1: Lab	ora	ator	·у Т	Test	Res	sults	on t	the	Soil	Sa	mples C	Colle	ecte	d fr	om	KM	[. 10	2 Lo	catio	n				
p						C	lay									Sie	eve A	naly	ysis			xial est	Be She	ox ear	(kPa)		
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L-3.50	21	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	13	58	29	21.1	32.4	-	1	-	1	SM
3.50-7.50	42	SS	Sandy Clayey Silt	8	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
7.50-10.50	50	SS	Silty Sand	7	-	-	-	-	2.65	-	20	-	₽-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM
10.50-12.00	62	SS	Silty Sand	6	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

conducte	Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 102												
Location of Bore Hole	Depth of Sample below E.G.L. (m)	hф	Chlorides(ppm)	Sulphates (ppm)									
BH-01	7.50	7.83	91.42	76									

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 3.50m depth below)

Type of Strata

Colour

Brownish
Thickness of Layer

SPT of the layer

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.30 Deg.

* Layer-2 (from 3.50m to 7.50m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 4.00m
SPT of the layer 42
Relative Density Dense
Angle of Shearing Resistance, φ 39.20 Deg.

* Layer-3 (from 7.50m to 10.50m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Fine Sand

Greyish

3.00m

50

Dense

41.00 Deg.

* Layer-4 (from 10.50m to 12.00m depth below)

Type of Strata Silty Fine Sand
Colour Greyish
Thickness of Layer 1.50m

SPT of the layer 62

Relative Density Very Dense Angle of Shearing Resistance, φ 42.50 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	20	44
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 102 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: $0.00\,$ m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 21

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 33.30 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 28.23$

 $N_{\gamma} = 39.32$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_{\rm u} = 552.49 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 220.99 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 21 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 12/06/2008; Ended On: 13/06/2008 G.W.T: 7.50m

טונ	пис	u O	11.12/(76/2008; Elided Oll: 13/	00/200	70	U.1	٧.1.	7.50			
					SP	Γ - D	etail	S	irapi	nical Representation of SP	×	
									##	10 20 30 40 50 60 70 80 90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
				Brownish	1.50	6	8	10	18	q	M.Dense	SS
		•		Medium Dense Silty Fine Sand	3.00	UDS	Samp	ler Ins	talled		M.Dense	UDS
					4.50	6	10	11	21		M.Dense	SS
					6.00	7	11	17	28		M.Dense	SS
7.	50	↓			7.50	10	13	20	33	\	Dense	SS
				Brownish Dense Silty Fine Sand	9.00	12	18	24	42	}	Dense	SS
					10.50	16	22	26	48	$\Big $	Dense	SS
12	.00	-			12.00	20	25	29	54	J	Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-103 Location**

		T	able 2.1: Lab	orato	ory	Tes	st R	esul	lts oı	n the	e So	il Sa	amp	oles Coll	lecto	e d fi	rom	KN	I-1 0	3 L	ocat	ion					
pu						C	lay									Sie	eve A	naly	/sis			axial est		ox ear	(kPa)		
R.L of Sample below Existing Grou level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-7.50	22	SS	Silty Sand	10	-		_	_	2.67		17		_	M.Dense	0	0	0	81	19	0	17.8	32.5					SM
B.G.L-7.30	22		Silty Salid	10	<u> </u>	_	_	_	2.07		1 /	_	ļ-	WI.DCHSC				01	1)		17.0	32.3			_	_	2141
7.50-12.00	41	SS, UDS	Silty Sand	8	-	-	-	-	2.65	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

	ed on V		nalysis Result ple collected f M-103	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нф	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.81	78.66	89.43

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 7.50m
SPT of the layer 22

Relative Density Medium Dense Angle of Shearing Resistance, φ 33.60 Deg.

* Layer-2 (from 7.50m to 12.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Fine Sand

Brownish

4.50m

41

Dense

38.975 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.80m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 1.80m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.80	19	46
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.80m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.80m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 103 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.80

Observed Maximum thickness of Filled up Soil: 0.00 m m

Effective Depth of Foundation below E.G.L: 1.80

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 18

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 32.40 Deg.

1 Design Parameters:

kN/m³ Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00

Effective Overburden pressure at foundation level (q) 10.80 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 25.55$

 $N_{\gamma} = 34.70$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_{\rm u} = 497.56 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 199.02 kPa

Limited to an allowable bearing pressure per running meter width: 190.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 190kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 190kPa and SPT of 18 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 11/06/2008; Ended On: 12/06/2008 G.W.T: 7.50m

ы	arte	u O	11.11/0	06/2008; Ended On: 12/					7.50					
					SP'	T - D	etail	S	rapl	nical Rep	resentati	on of SP	≿	
									##	10 20 30	(4(5)6(7(8(90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value				Relative Density/Consistency	Type of Sample
				Brownish Loose Silty Fine Sand	1.50	4	6	7	13	9			Loose	SS
4	.50				3.00 4.50	UDS 7	Samp 9	ler Ins	talled				Loose M.Dense	UDS SS
				Brownish Medium Dense Silty Fine Sand	6.00	7	11	17	28				M.Dense	SS
7	.50	↓		Greyish to Brownish	7.50 9.00	10	14	21	35 44	(Dense Dense	SS SS
				Dense Silty Fine Sand	10.50	17	23	27	50				Dense	SS
12	2.00	<u> </u>			12.00	20	24	30	54		l		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-104 Location**

		T	able 2.1: Lab	ora	tor	y T	est	Res	sults	on 1	the	Soil	Sa	mples (Coll	ecte	d fr	om	KN	1-1 0	94 Lo	cati	on				
рі						Cl	lay									Sie	ve A	naly	sis		Tria Te			ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	(%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-4.50	13	SS, UDS	Silty Sand	13	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	86	14	0	11.2	30.0	-	-	-	-	SM
4.50-7.50	25	SS	Silty Sand	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
7.50-12.00	43	SS	Silty Sand	7	1	-	-	-	2.65	-	19	-	-	Dense	0	0	0	77	23	0	-	-	-	1	-	-	SM

conducte	d on V	Vater S	analysis Resu ample collect at KM-104	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.80	68.76	78

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Fine Sand

Brownish

4.50m

13

Loose

30.90 Deg.

* Layer-2 (from 4.50m to 7.50m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 3.00m
SPT of the layer 25

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 34.50 Deg.

* Layer-3 (from 7.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 4.50m SPT of the layer 43 Relative Density Dense Angle of Shearing Resistance, φ 39.425 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	15	45
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 104 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 13

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.90 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 21.08$

 $N_{v} = 27.01$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_{\rm u} = 375.37 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 150.15 kPa

Limited to an allowable bearing pressure per running meter width: 150.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 12/06/2008; Ended On: 13/06/2008 G.W.T: 6.30m

Startee	I OII	. 12/0	6/2008; Ended On : 13/0				V.1: (1 D	. capa	ı	
				SP	T - D	etail	S		_	cal Representat			
								0	10	20 30 40 50 6	50 70 80 90	ıcy	
Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value				Relative Density/Consistency	Type of Sample
			Brownish Loose Silty Fine Sand	1.50	4	6	7	13	١	to		Loose	SS
				3.00			er In sta					Loose	UDS
4.50 G.W.T	+		Brownish Medium Dense	6.00	10	9	13	19				M.Den se	ss ss
7.50			Silty Fine Sand	7.50	12	15	17	32		\		Dense	SS
			Greyish to Brownish Dense	9.00	15	20	23	43				Den se	SS
			Silty Fine Sand	10.50	17	23	27	50				Dense	SS
12.00		\mathbf{H}		12.00	20	24	30	54		I		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at KM-105 Location

Clay Sieve Analysis Triaxial Box Test Shear Shea		Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-105 Location																												
Note Part	q						C	lay									Sie	eve A	nal	ysis								kPa)		
4.50-7.50 22 SS Silty Sand 10 2.7 - 17 - M.Dense 0 0 0 83 17 0 SM	R.L of Sample below Existing Groun level(m)	of	of	Engineering Classification of		TT (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Gravity,		Bulk Density, kN/m ³	Free Swell (%)			Gravel (%)	Coarse (%)		Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Compression Tests, Cu	Tests,	IS-Classification		
4.50-7.50 22 SS Silty Sand 10 2.7 - 17 M.Dense 0 0 0 83 17 0 SM																														
	E.G.L-4.50	13	SS, UDS	Silty Sand	13	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	84	16	0	13.1	28.9	-	-	-	-	SM		
7.50-12.00 42 SS Silty Sand 7 2.7 - 19 Dense 0 0 0 74 26 0 SM	4.50-7.50	22	SS	Silty Sand	10	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	83	17	0	-	-	-	-	-	-	SM		
7.50-12.00 42 SS Silty Sand 7 2.7 - 19 Dense 0 0 0 74 26 0 SM																														
	7.50-12.00	42	SS	Silty Sand	7	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	74	26	0	-	-	-	-	-	-	SM		

	ed on Wat		alysis Result le collected fi A-105	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.79	90.49	94.31

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Fine Sand

Brownish

4.50m

13

Loose

30.90 Deg.

* Layer-2 (from 4.50m to 7.50m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 3.00m
SPT of the layer 22

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 33.60 Deg.

* Layer-3 (from 7.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 4.50m SPT of the layer 42 Relative Density Dense Angle of Shearing Resistance, ϕ 39.20 Deg.

The ground water table was encountered at a depth of 6.30m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	15	45
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 105 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 13

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.90 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 21.08$

 $N_{v} = 27.01$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_{u} = 375.37 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 150.15 kPa

Limited to an allowable bearing pressure per running meter width: 150.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 106(000-100) (MEERUT - SAHARANPUR SECTION)

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC. Started On: 13/06/2008; Ended On: 14/06/2008 G.W.T: 7.50m

Starte	ou O	11.13/	J6/2008; Ended On : 14	+/00/20	700		<u> 1. YY .</u>		.50m
				SPT	Γ - Γ)etai	ls	Gra	aphical Representation of SPT
								0	10 20 30 40 50 60 70 80 90
Depth of Top of	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency Commission of C
			Brownish Loose Silty Fine Sand	1.50	4	4	6	10	- S:
4.50			Sity The Said	3.00	UDS 7	Samp 10	oler In	estalle	ed Loose UI
7.50	•		Brownish Medium Dense Silty Fine Sand	6.00	9	11	14	25	M. Dense S: M. Dense S: Dense S:
			Greyish to Brownish	9.00	12	15	20	35	Dense S:
			Dense Silty Fine Sand	10.50	16	20	23	43	Dense S:
12.00		3888		12.00	16	24	27	51	V.Dense S

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-106 (000-100) Location

IR KM 106(000-100) (MEERUT - SAHARANPUR SECTION)

		Ta	ble 2.1: Labo	ratory	Tes	t R	esu	lts (on the	Soil	Sa	mpl	es (Collecte	d fr	om	KN	I-1 ()6 (C	000-	100) Lo	catio	n					
pu						C	lay													Box 8		Box S		Triaxial Test		Shear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification		
F.G.L. 4.50	10	gg	gii. g 1	1.5					2.67	0.4	1.5			_		_	_	0.1					10.0	20.2			G) (
E.G.L-4.50	10	SS	Silty Sand	15	-	-	-	-	2.67	0.4	15	-	-	Loose	0	0	0	91	9	0	-	-	10.9	29.3	-	-	SM		
4.50-7.50	23	SS	Silty Sand	10	-	-	-	-	2.66	0.27	17	-	-	M.Dense	0	0	0	84	16	0	-	-	-	-	-	-	SM		
7.50-12.00	36	SS	Silty Sand	9	_	_	_	_	2.65	0.24	18	_	_	Dense	0	0	0	79	21	0	_	_	_	-	_	_	SM		
7.50 12.00	50	55	only band						2.00	3.2T	10			Dense				,,	2.								5111		

conduc	ted or	n Wate	l Analysis Ro r Sample coll KM.106 (000	ected
Location of Bore Hole	Depth of Sample below E.G.L. (m)	hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.86	119.35	104.67

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at KM- 106(000-100) Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Silty Fine Sand

Brownish

4.50m

Loose

30.00°

* Layer-2 (from 4.50m to 7.50m depth below)

Type of Strata Silty Fine Sand
Colour Brownish
Thickness of Layer 3.00m
SPT of the layer 23

Relative Density Medium Dense

Angle of Shearing Resistance 33.90°

* Layer-3 (from 7.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish to Brownish

Thickness of Layer 4.50m SPT of the layer 36 Relative Density Dense Angle of Shearing Resistance 37.65°

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the third week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	2.00	12	44
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- The sub-soil stratifications encountered at shallow depths i.e. immediately as
 top sub-surface strata are coarse-grained type in the form of silty sand and can
 be considered as bearing strata for the proposed impending loads from the
 superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 106(000-100) (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00 m

Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 10

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 30.00 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 18.40$

 $N_{\gamma} = 22.40$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_{\rm u} = 323.20 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 129.28 kPa

Limited to an allowable bearing pressure per running meter width: 120.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 10 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC. Started On: 12/06/2008; Ended On: 12/06/2008 G.W.T: 9.00m

Sta	I te	u O	11.12/	06/2008; Ended On : 1	2/00/20	100		i. vv .		.00m	
					SP	Γ - Γ	etai	ls	Gra	aphical Representation of SPT	
									0	10 20 30 40 50 60 70 80 90	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
					1.50	7	11	14	25	M. Dense	SS
	•			Brownish Medium Dense	3.00	UDS	Colle	cted		M. Dense	SS
				Sandy Clayey Silt	4.50	6	10	12	22	M. Dense	SS
					6.00	12	12	15	27	M. Dense	SS
					7.50	10	13	17	30	M. Dense	SS
9.0	00	¥	5 000 C		9.00	18	24	29	53	V. Dense	SS
				Greyish Very Dense Silty Fine Sand	10.50	20	26	29	55	V. Dense	SS
12.	00	┟┤			12.00	26	30	32	62	V. Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.108 Location

		T	able 2.1: Lab	orator	y T	'est	Re	sult	s on	the	Soil	San	ıpl	es Colle	cte	d fre	om 1	KM	. 10	8 L	ocati	ion					
nd						C	lay	1								Sie	ve A	naly	ysis			est		ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	Ы	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-9.00	26	SS	Sandy Clayey Silt	10	-	-	-	-	2.66	-	18	-	-	M.Dense	0	0	0	26	58	16	19.1	33.9	-	-	-	-	SM
9.00-12.00	54	SS	Silty Sand	8	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM

		er Sam _]	nalysis Resul ple collected f M. 108	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.77	156.54	126.43

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 9.00m depth below)

Type of Strata Sandy Clayey Silt Colour Brownish

Thickness of Layer 6.00m SPT of the layer 26

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.80 Deg.

* Layer-2 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand

 $\begin{array}{lll} \mbox{Colour} & \mbox{Greyish} \\ \mbox{Thickness of Layer} & 3.00 \mbox{m} \\ \mbox{SPT of the layer} & 54 \\ \mbox{Relative Density} & \mbox{Dense} \\ \mbox{Angle of Shearing Resistance, } \phi & 41.60 \mbox{ Deg.} \end{array}$

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	25	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 108 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 25

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 34.50 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 31.81$

 $N_{\gamma} = 45.47$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_{\rm u} = 627.44 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 250.98 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 25 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at $\label{eq:Km156} Km156\ on\ Eastern\ Freight\ Corridor\ in\ line\ with\ Tender\ No.\ HQ/EN/Pre.\ (Works)/MTC.$ Started On: 10/06/2008; Ended On: 10/06/2008 G.W.T: 10.00m

St	arte	u O	II . 10/C	76/2008; Ended On: 10/	00/200	70	U.1	W . I .	10.0	JOH		
					SP	Γ - D	etail	S	rapl	hical Representation of SP	y	
									##	10 21 31 41 51 61 71 81 90	oue	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		Relative Density/Consistency	Type of Sample
				Brownish	1.50	9	12	14	26	j	M.Dense	SS
		•		Medium Dense Sandy Clayey Silt	3.00	7	11	10	21	4	M.Dense	SS
					4.50	11	14	16	30		M.Dense	SS
6	.00		8888		6.00	13	15	17	32		Dense	SS
				Greyish Dense	7.50	15	19	28	47		Dense	SS
10	0.00	↓		Silty Fine Sand	9.00	17	23	26	49		Dense	SS
				Greyish Very Dense	10.50	20	27	30	57	\ \ \	V.Dense	SS
12	.00			Silty Fine Sand	12.00	24	30	32	62	}	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM.109 Location**

			Table 2.1: L	aborato	ry 🛚	Гes	t Re	esul	ts o	n the	e So	il Sa	ımp	oles Col	llect	ted	froi	n K	М.	109	Loc	cation	ì				
pu						C	lay									Sie	ve A	nal	ysis			axial est	Bo Sho	ox ear	(kPa)		
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	$c~(kN/m^2)$	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-6.00	26	SS	Sandy Clayey Silt	11	-	-	-	-	2.7	-	18	-	-	M.Dense	0	0	0	21	55	24	16.5	34.1	-	-	-	-	SM
6.00-10.00	43	SS	Silty Sand	9	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
10.00-12.00	57	SS	Silty Sand	7	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	74	26	0	-	-	-	-	-	-	SM
			·																								

conduc	cted or	1 Wate	l Analysis R r Sample col e at KM. 109	lected
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.89	144.32	121.46

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 6.00m depth below)

Type of Strata Sandy Clayey Silt Colour Brownish

Thickness of Layer 6.00m SPT of the layer 26

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.80 Deg.

Layer-2 (from 6.00m to 10.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 4.00m
SPT of the layer 43
Relative Density Dense
Angle of Shearing Resistance, φ 39.425 Deg.

* Layer-3 (from 10.00m to 12.00m depth below)

Type of Strata Silty Fine Sand

Colour Greyish
Thickness of Layer 2.00m
SPT of the layer 57

Relative Density Very Dense Angle of Shearing Resistance, φ 42.05 Deg.

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	25	48
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 109 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 26

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 34.80 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 32.70$

 $N_{\gamma} = 47.00$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 646.18 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 258.47 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 26 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project : Proposed Dedicated Freight Comidor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on $Eastem\ Freight\ Corridor\ in\ line\ with\ Tender\ No.\ HQ/EN/Pre.\ (Works)/MTC.$

Started On: 12/06/2008: Ended On: 12/06/2008

Star	ted	On	: 12/00	6/2008; Ended On: 12/0)6/200	8	G.W	/.T: 9	9.201	n										
					SP	T - D	etails	3	G	raphi	ical	Rep	rese	enta	tion	of	SP	Γ		
									0	10) 2	030	40	50	60 7	70 8	309	0	ıcy	
Depth of Top of	Lay er(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value										Relative Den sity/Con sistency	Type of Sample
			ĮΤΙ	Filled Up																
1.6	60	Ц	╿┋┋	Soil	l															
					2.00	8	10	12	22		(M.Den se	SS
				Brownish Medium Dense	3.00	UDS	Co llecte	ed											M.Den se	SS
				Silty Clayey Fine Sand	4.50	10	14	15	29										M.Den se	SS
					6.00	9	13	17	30			1							M.Den se	SS
7.5	50				7.50	8	16	19	35			ļ							Dense	SS
				Greyish									\							
G.V	v.T	₩		Dense	9.00	15	22	28	50					/					Dense	SS
10.	00			Silty FineSand										\	\					
	_	Ш		Greyish	10.50	20	29	36	65						P				V.Den se	SS
		[_]		Very Dense											1					
12.	00	<u> </u>		Silty Fine Sand	12.00	22	32	35	67										V.Den se	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level Fig. 2.1 Soil Profile at KM.110 Location

			Table 2.1: I	aborat	tory Tes	t R	lesu	lts (on tl	ne S	oil Sar	nple	es C	Collecte	d fr	om	KN	/I-1	10 I	Joca	ation	1					
p						Clay	7									Sie	ve A	naly	ysis			xial est	Be She	ox ear	(kPa)		
R.L. of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, L _c	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression Tests, Cu (Consolidation Tests, Cc	IS-Classification
E.G.L-1.60	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.60-7.50	27	SS, UDS	Silty Sand	11	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	83	17	0	12.8	34.7	-	-	-	-	SM
7.50-10.00	42	SS	Silty Sand	8	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
10.00-12.00	65	SS	Silty Sand	6	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

	ducted on	nemical Anal Water Sam ore Hole at K	ple coll	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hq	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.79	145.32	100.34

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 1.60m depth below)

Type of Strata Filled Up Soil

Colour -

Thickness of Layer 1.60m SPT of the layer - Relative Density - Angle of Shearing Resistance, φ -

* Layer-2 (from 1.60m to 7.50m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 5.90m
SPT of the layer 27

Relative Density Medium Dense Angle of Shearing Resistance, ϕ 35.10 Deg.

* Layer-3 (from 7.50m to 10.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 2.50m
SPT of the layer 42
Relative Density Dense
Angle of Shearing Resistance, ϕ 39.20 Deg.

* Layer-4 (from 10.00m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 2.50m
SPT of the layer 65

Relative Density Very Dense Angle of Shearing Resistance, φ 42.50 Deg.

The ground water table was encountered at a depth of 9.20m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level i.e. 3.10m below existing ground level (considering 1.60m thick fill). The safe bearing capacity of proposed foundation system at a

recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	22	44
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level i.e. 3.10m below existing ground level (considering 1.60m thick fill). The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 110 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 3.10 n

Observed Maximum thickness of Filled up Soil: 1.60 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00

1 Soil Data:

Type of Bearing Strata: Silty Sand

Least SPT-value of the Bearing Strata: 22

Type of Shear Failure: General

Angle of Shearing Resistance, \$\psi\$: 33.60 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 29.13$

 $N_{\gamma} = 40.85$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C^+}q*(Nq\text{-}1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 571.23 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 228.49 kPa

Limited to an allowable bearing pressure per running meter width: 220.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 22 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

Project: Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 14/06/2008; Ended On: 14/06/2008 G.W.T: 9.50m

שני	пис	ı O	11 . 1 7/(76/2008; Elided Oll: 14/					9.50			
					SP'	Τ - D	etail	S	rapl	hical Representation of SP	Y	
							enc					
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	10 21 3(4(5) 6(7(8) 90	Relative Density/Consistency	Type of Sample
1.	50			Greyish to Brownish Loose Silty Fine Sand	1.50	8	10	12	22	9	M.Dense	SS
		•		Brownish	3.00	UDS	Colle	cted			M.Dense	SS
				Medium Dense Sandy Clayey Silt	4.50	10	13	15	28	0	M.Dense	SS
					6.00	11	12	14	26	4	M.Dense	SS
7.	50				7.50	15	19	23	42	Į į	Dense	SS
				Greyish Dense								
_	00	Н		Silty Fine Sand	9.00	18	24	29	53		V.Dense	SS
G.V	V.T	↓ .		Greyish Very Dense	10.50	26	30	34	64		V.Dense	SS
12	.00			Silty Fine Sand	12.00	21	29	35	64	d	V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-112 Location**

IR KM 112 (MEERUT - SAHARANPUR SECTION)

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 112 Location																										
isting Ground			Visual &	<u>Laborat</u>			lay	Kest			80	II Sa			Sieve Analysis Test Shear												
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, \mathbf{I}_{C}	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression	Consolidation Tests, Cc	IS-Classification
E.G.L-1.50	-	SS	Silty Sand	14	_	_	-	1	2.68	_	15	-	-	Loose	0	0	0	91	9	0	-	-	-	_	-	-	SM
1.50-7.50	25	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	23	65	12	13.2	33.7	-	-	-	-	SM
7.50-9.00	42	SS	Silty Sand	8	-	_	-	ı	2.66	-	19	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM
9.00-12.00	59	SS	Silty Sand	6	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	72	28	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 112										
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)						
BH-01	12.00	7.78	155.32	143.22						

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 1.50m depth below)

Type of Strata

Colour

Greyish to Brownish

Thickness of Layer 1.50m
SPT of the layer Relative Density Loose
Angle of Shearing Resistance, φ -

* Layer-2 (from 1.50m to 7.50m depth below)

Type of Strata Sandy Clayey Silt

Colour Brownish
Thickness of Layer 6.00m
SPT of the layer 25

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.50 Deg.

* Layer-3 (from 7.50m to 9.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance, φ

Silty Fine Sand

Greyish

1.50m

42

Dense

39.20 Deg.

* Layer-4 (from 9.00m to 12.00m depth below)

Type of Strata Silty Fine Sand
Colour Greyish
Thickness of Layer 3.00m

SPT of the layer 59

Relative Density Very Dense Angle of Shearing Resistance, φ 42.35 Deg.

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

IR KM 112 (MEERUT - SAHARANPUR SECTION)

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	22	44
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 112 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 112 (MEERUT - SAHARANPUR SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 1.50 m

Observed Maximum thickness of Filled up Soil: 0.00 m Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Silt

Least SPT-value of the Bearing Strata: 22

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 33.60 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 29.13$

 $N_{\gamma} = 40.85$

Shape Factors:

 $S_c = N/A$

 $S_{q} = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{y} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 571.23 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

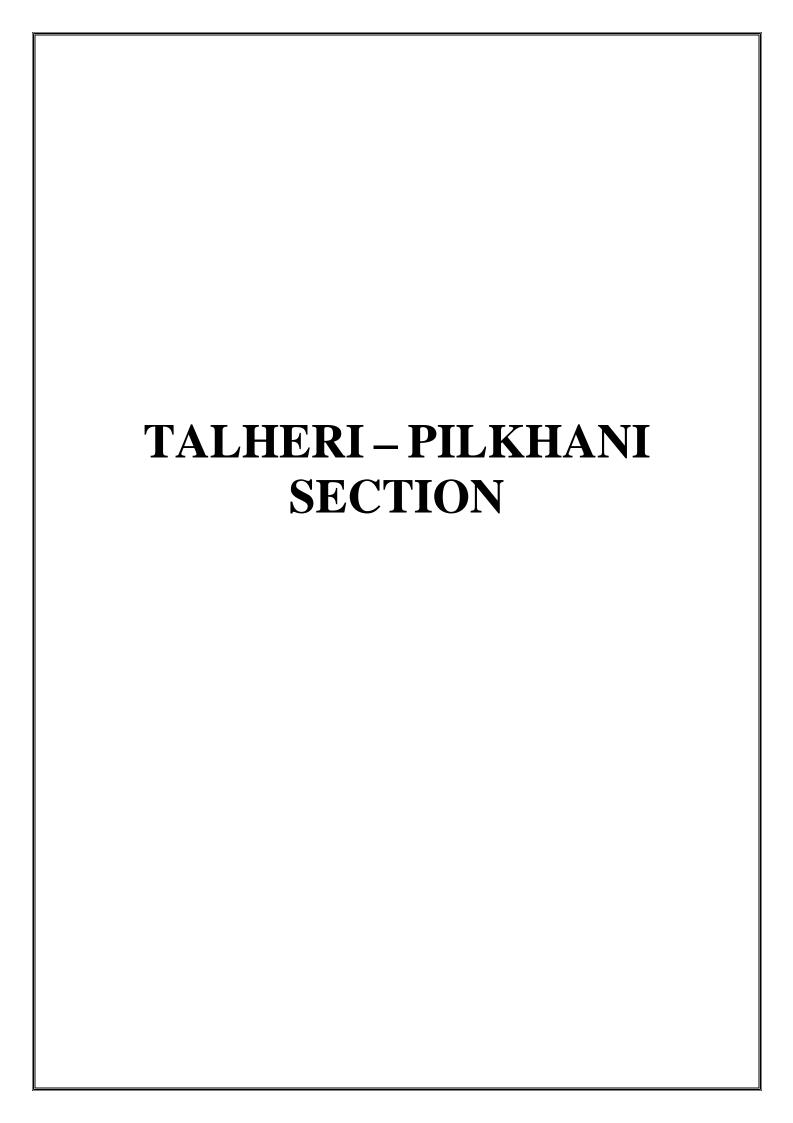
Factor of Safety (F.S.): 2.50

Qsafe: 228.49 kPa

Limited to an allowable bearing pressure per running meter width: 220.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 22 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.



Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 07/07/2008; Ended On: 07/07/2008 G.W.T: 5.50m

	art			11 . 0 // (57/2008, Elided Oll . 07/					3.30				-	, .		COI	ы		1
						SP	I - D	etail	S	rapi	nical R							_	S.	
										##	10 2	2(3	(4(516	5('	7(8	190)	enc	
Depth of Top of	I oxion(m)	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value									Relative Density/Consistency	Type of Sample
					Greyish to Brownish Medium Dense	1.50	8	12	13	25		9	-			-	-		M.Dense	SS
		4	•		Sandy Clayey Silt	3.00	UDS	Colle	cted										M.Dense	SS
5	.50	,	ţ			4.50	10	12	12	24	,	d							M.Dense	SS
					Brownish Medium Dense Silty Fine Sand	6.00	8	11	17	28		4							M.Dense	SS
7	.50)				7.50	12	16	17	33		d							Dense	SS
			 		Greyish	9.00	13	15	18	33		d							Dense	SS
			 		Dense Silty Fine Sand	10.50	18	20	22	42				\					Dense	SS
1:	2.00	0				12.00	20	25	25	50									Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-155 Location**

		Tab	le 2.1: Labora	tory Te	st I	Res	ults	on t	the S	Soil S	San	ples	Co	llected	fror	n K	M. 1	155	Loc	atio	n						
round						C	lay									Sie	eve A	analy	sis			est	She	ox ear	Cu (kPa)		
R.L. of Sample below Existing Glevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	Id	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	♦ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests,	Consolidation Tests, Cc	IS-Classification
E.G.L-5.50	24	SS	Sandy Clayey Silt	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	21	55	24	14.5	33.6	-	-	-	-	SM
5.50-7.50	28	SS	Silty Sand	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
7.50-12.00	36	SS	Silty Sand	8	-	_	_	-	2.65	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Che Water Sample		•		
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нq	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.82	90.39	95.64

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 5.50m depth below)

Type of Strata Sandy Clayey Silt Colour Greyish to Brownish

Thickness of Layer 5.50m SPT of the layer 24

Relative Density Medium Dense Angle of Shearing Resistance, φ 34.20 Deg.

* Layer-2 (from 5.50m to 7.50m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 2.00m
SPT of the layer 28

Relative Density Medium Dense Angle of Shearing Resistance, φ 35.40 Deg.

* Layer-3 (from 7.50m to 12.00m depth below)

Angle of Shearing Resistance, ϕ

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Silty Fine Sand

Greyish

4.50m

36

Dense

The ground water table was encountered at a depth of 5.50m within the explored depth of investigation in the first week of July 2008.

37.65 Deg.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of	Recommended	Safe Bearing	Elastic
	Foundation	Minimum	Capacity	Settlements
	Structure	Depth of	(t/m^2)	(mm)
		Footing below		
		N.G.L		
		(m)		
1	Isolated	1.50	25	40
	Column			
	Footing/Raft			

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
- 3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
- 4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
- 5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 155 (TALHERI - PILKHANI SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

 $\begin{tabular}{lll} Type of Footing: Isolated Column\\ Depth of foundation below the E.G.L: 1.50 & m\\ Observed Maximum thickness of Filled up Soil: 0.00 & m\\ \end{tabular}$

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Sandy Clayey Silt

Least SPT-value of the Bearing Strata: 25

Type of Shear Failure: General

Angle of Shearing Resistance, \$\phi\$: 34.50 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 17.00 kN/m^3

Effective Overburden pressure at foundation level (q) 10.50 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 31.81$

 $N_{\nu} = 45.47$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{v} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

$$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$$

 $Q_u = 627.44 \ kPa$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 250.98 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 25 are computed to be in the order of 40mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

 $Project: Proposed\ Dedicated\ Freight\ Corridor\ from\ Kulwa\ to\ Khurja\ , Khurja\ to\ Dadri\ and\ Khurja\ to\ Talheri\ at$ Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On: 07/07/2008; Ended On: 07/07/2008 G.W.T: 5.00m

<u> </u>	arte	u O	n:0//0	07/2008; Ended On: 07/					5.00									
					SP'	T - D	etail	S	rapl	nical	Re	pres	enta	tio	n of	SP	<u></u>	
									##	10	2(3(4	(516	5(7	(8)	90	enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
				Greyish to Brownish	1.50	6	7	8	15	q							Stiff	SS
4	.00	•		Stiff Silty Sandy Clay	3.00	UDS	Colle	cted									Stiff	SS
G.	w.T	<u></u>			4.50	5	8	10	18		d						M.Dense	SS
		 			6.00	8	10	11	21								M.Dense	SS
		 		Brownish Medium Dense Silty Fine Sand	7.50	10	10	15	25		9						M.Dense	SS
		 			9.00	11	14	15	29		d						M.Dense	SS
10	0.50		0000	Greyish	10.50	18	23	28	51			\	7				V.Dense	SS
		 		Very Dense									\					
12	2.00			Silty Fine Sand	12.00	20	26	31	57				J				V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at KM-156 Location**

		Ta	ble 2.1: Labo	ratory	Tes	st R	esu	lts (on th	ne S	oil S	Sam	ple	s Collec	cted	fro	m I	KM.	-156	Lo	cation						
																					Triax	xial	В	ox	a)		
pu						C	lay									Sie	eve A	nal	ysis		Tes	st	Sh	ear	(kPa)		
R.L. of Sample below Existing Groun level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	TT (%)	PL (%)	PI	Consistency, I _C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
E.G.L-4.00	15	SS, UDS	Silty Clay	33	78	31	47	1	2.67	0.88	17	65	60	Stiff	0	0	0	0	24	76	96.9	14.3	-	-	100.0	0.61	CH
1 00 10 70			~ .		1											_				_							
4.00-10.50	23	SS	Silty Sand	8	-	-	-	-	2.66	0.21	18	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
10.50-12.00	51	SS	Silty Sand	6	-				2.65	0.16	20			V.Dense	0	0	0	73	27	0							SM
10.30-12.00	31	33	Siny Sand	0	-	-	-	-	2.03	0.10	20	-	-	v.Dense	U	U	0	/3	21	U	-	-	-	-	-	-	SIVI

		•	esults conduc ore Hole at K	
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Нd	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.86	100.17	99.64

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at KM- 156 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 4.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Consistency

Undrained Cohesion, Cu

Silty Sandy Clay

Brownish

4.00m

Stiff

15

Stiff

100.00kPa

* Layer-2 (from 4.00m to 10.50m depth below)

Type of Strata Silty Fine Sand Colour Greyish
Thickness of Layer 6.50m
SPT of the layer 23

Relative Density Medium Dense

Angle of Shearing Resistance 33.90°

* Layer-3 (from 10.50m to 12.00m depth below)

Type of Strata

Colour

Greyish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Silty Fine Sand

Greyish

3.00m

SPT of the layer

Very Dense

41.15°

The ground water table was encountered at a depth of 5.00m within the explored depth of investigation in the first week of July 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	
	(m)		
1	2.50	21	66

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.
- 2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
- 4. The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 156 (TALHERI - PILKHANI SECTION) DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.50 m Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Clay

Least SPT-value of the Bearing Strata: 15

Type of Shear Failure: General

Undrained Cohesion, Cu: 100.00 kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m^3

Effective Overburden pressure at foundation level (q) 15.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = 5.14$

 $N_q = N/A$

 $N_{\nu} = N/A$

Shape Factors:

 $S_c = 1.30$

 $S_q = N/A$

 $S_{\gamma} = N/A$

Depth Factors:

 $D_c = 1.00$

 $D_q = N/A$

 $D_{\gamma} = N/A$

Inclination Factor:

 $I_c = 1.00$

 $I_q = N/A$

 $I_v = N/A$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 668.20 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

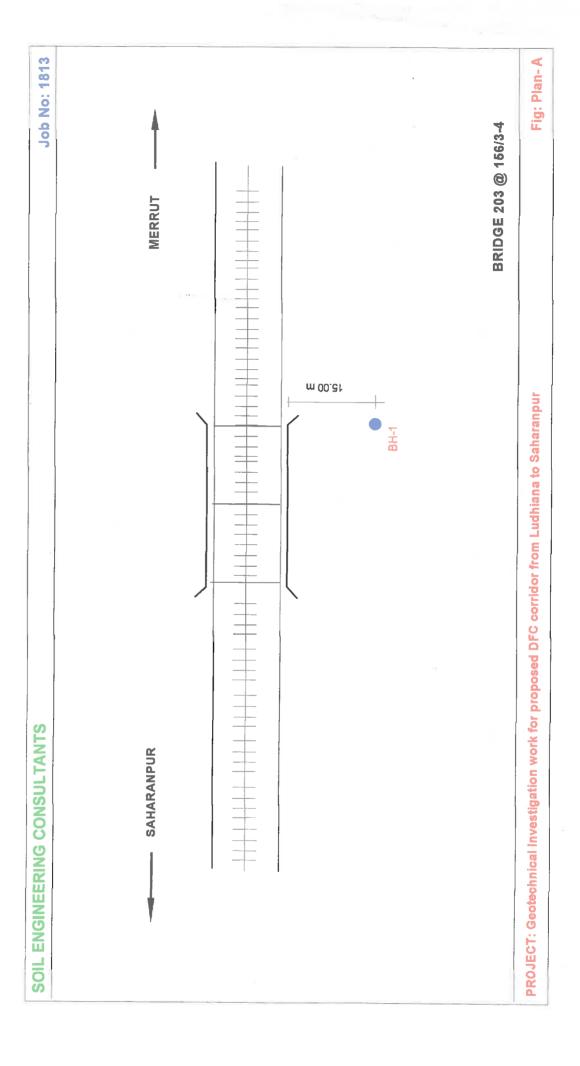
Factor of Safety (F.S.): 2.50

Qsafe: 267.28 kPa

Limited to an allowable bearing pressure per running meter width: 210.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 210kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 210kPa and SPT of 15 are computed to be in the order of 66mm which is within the permissible limits of 70mm for rafts as per LS:1904.



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Location; 168/3-4 BH No.: 1 Depth : 12.00 Depth of Water table : Not Met

RL: 259.850

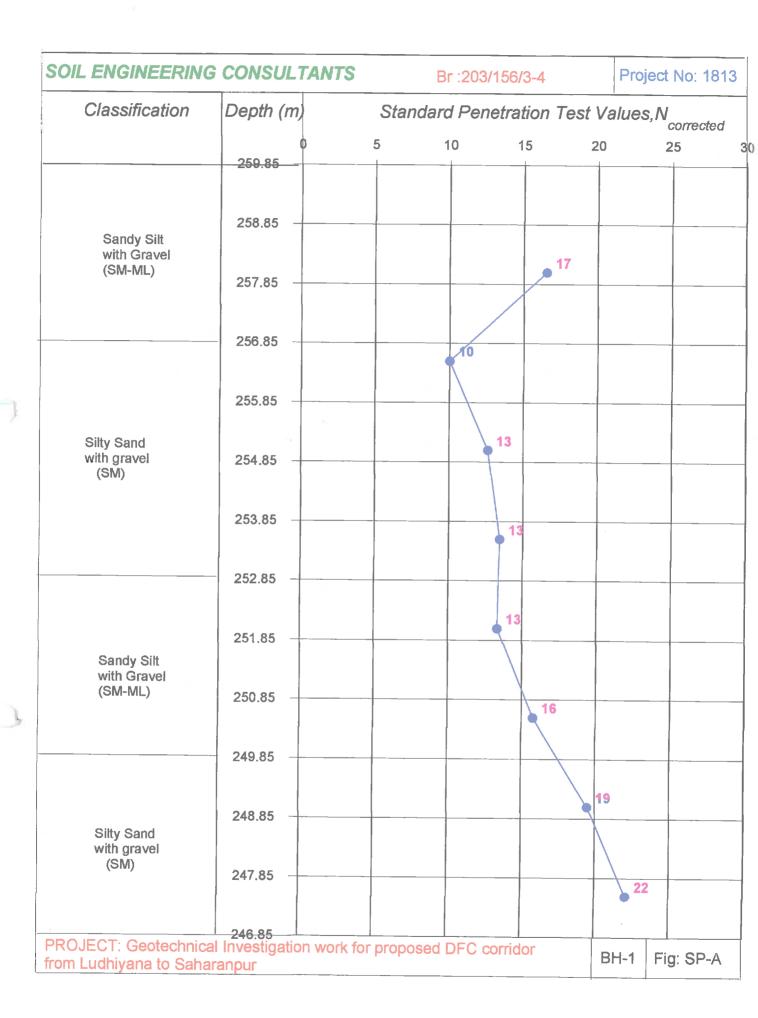
Bridge: 203

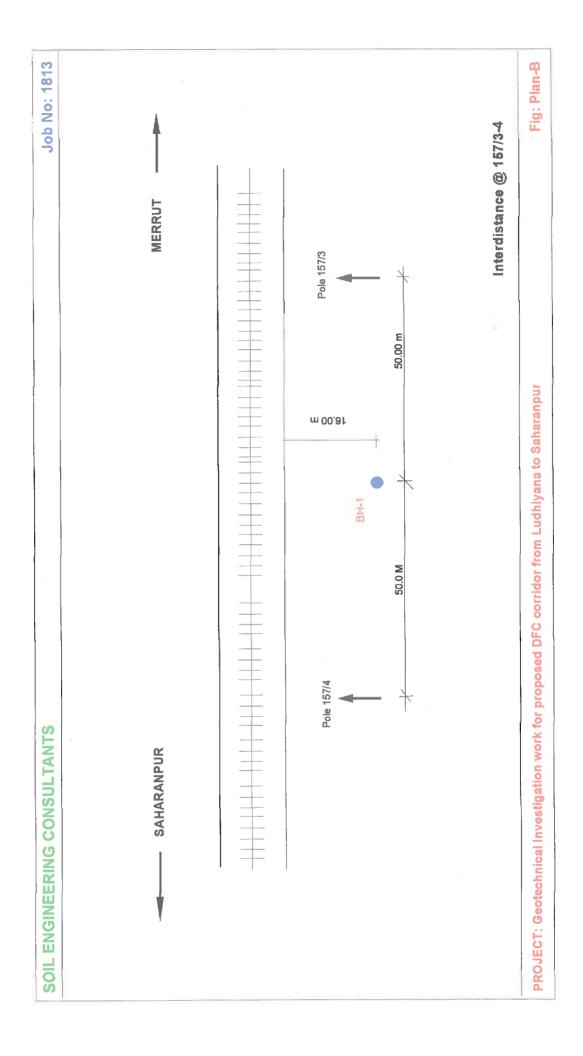
Project No. 1813

Date of start : 15/07/2008

Date of finish: 15/07/2008

		Ç			0.071				_								
	ters	(essrees)			9				30								
	Shear Parameters	C(kg/sq.cm)			0.53				0.15								
	Shear	Type of test			00				DST								
		Sp.Gr			2.69		_		2.65								
	Limits (%)	P.L	Non Plastic	Non Plastic		22		Non Plastic		Non Plastic		Non Plastic	Non Plastic		Non Plastic		Non Plastic
	Limi	ΓΓ	No.	8		46		Non		Non		Non	Non		Non		Non
	W/C	(%)M			11.92				14.13								
	sity /cc)	r(dry)		-	1.56		-		72.								
MANGE . NOT HIGH	Density (gm/cc)	r(wet)			1.75				1.76		_						
. DIAM	(%)	Silt/clay		80		80		86		92		00	86		40		96
	Grain size (%)	Sand		2		2		7		9		_	N	-	ဖ		4
	Gra	Gravel		0		0	_	0		2		0	0		0		0
		40 50														_	
	Plot	30													25		*30
		Observed		12				7		4		7 5	19				
	S.P.T	Obse		*		* 10		* 12		*		*					
		0	I.00 —	2.00		3.00	4.00	5.00		0.00	7.00	8.00	00.6	10.00	11.00	12.00	
-		no				- Ajio								-	7		
		Soil	Sandy Silt with Gravel (SM-ML)			Silty Clay of medium plasticity (CI)							Sandy Silt with Gravel (SM-ML)				
	smbje 	Type of s	SQ	SPT	SQN	SPT		SPT	SON	SPT		SPT	P G		SPT		SPT
	(m)	Depth	0.50	1.80	2.50	3.30		4.80	5.50	6.30		7.80	9.30		0.80		2.30
	[9v9.]	Keduced	259.350	258.050	257.350	256.550		255.050	254.350	253,550		252.050	250.550		249.050 10.80		247.550 12.30





Date of start 16/07/2008

Cc

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Shear Parameters phi(degrees) 9 8 8 3, 0.52 Date of finish: 17/07/2008 C(kg/sq.cm) 0.15 0.1 0.1 DST \exists DST DST Type of test 2.69 2.65 2.65 Sp.Gr Non Plastic Non Plastic Non Plastic Limits (%) Non Plastic Non Plastic P.L 0 22 300 99 TT W/C 14.46 (%)M 15.41 15.69 17.24 1.56 Density (gm/cc) 1.56 r(dry) 1.57 1.59 Location; 157/3-4
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met 1.78 r(wet) 86 <u>~</u> 82 Silt/clay 82 Grain size (%) 98 92 92 74 82 87 Dars 2 CV ~ ∞ 26 8 11 Gravel 9 0 0 0 0 N 40 32 30 S.P.T Plot 22 Observed 20 RL: 259.950 1.00 2.00 3.00 4.00 5.00 00.9 7.00 8.00 00.6 10.00 11.00 Silty Clay of medium Plasticity (CI) Classification Sandy Silt with Gravel (SM-ML) Soil Interdistance UDS SPT SPT NDS SPT SPT NDS SPT SPT UDS Type of sample SPT Project No. 1813 1.80 2.50 3.30 Depth (m) 4.80 5.50 6.30 7.80 8.50 9.30 249.150 10.80 248.450 11.50 258.150 450 259,950 256.650 255.150 254.450 253.650 252.150 251.450 250,650 Reduced Level 257.

Non Plastic

20

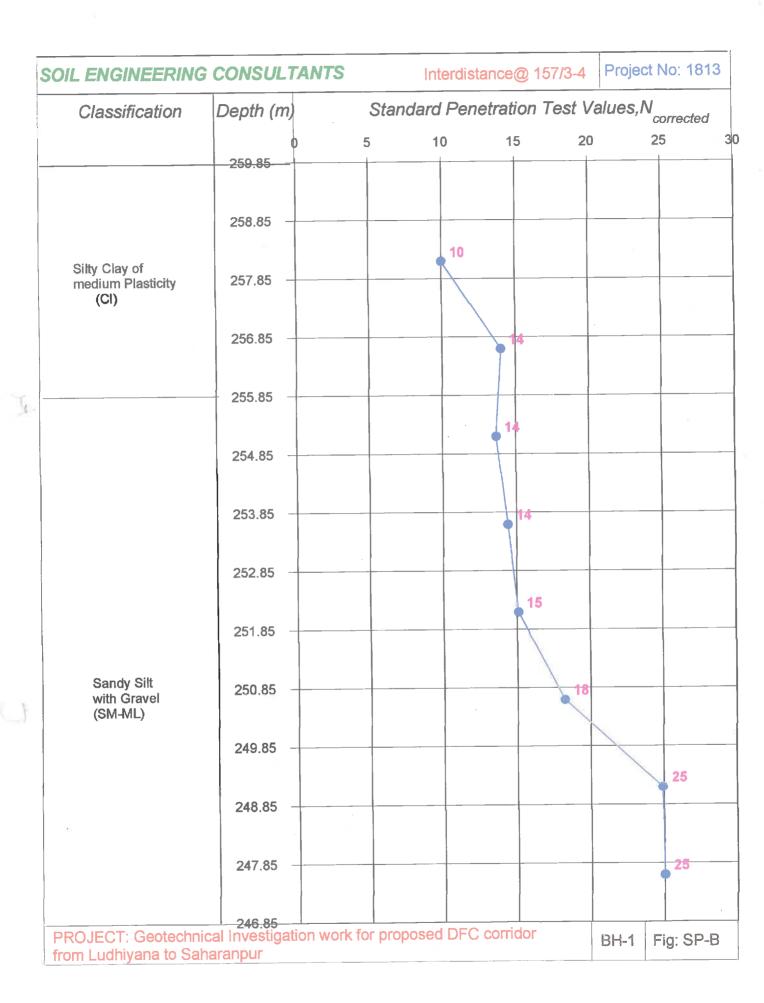
20

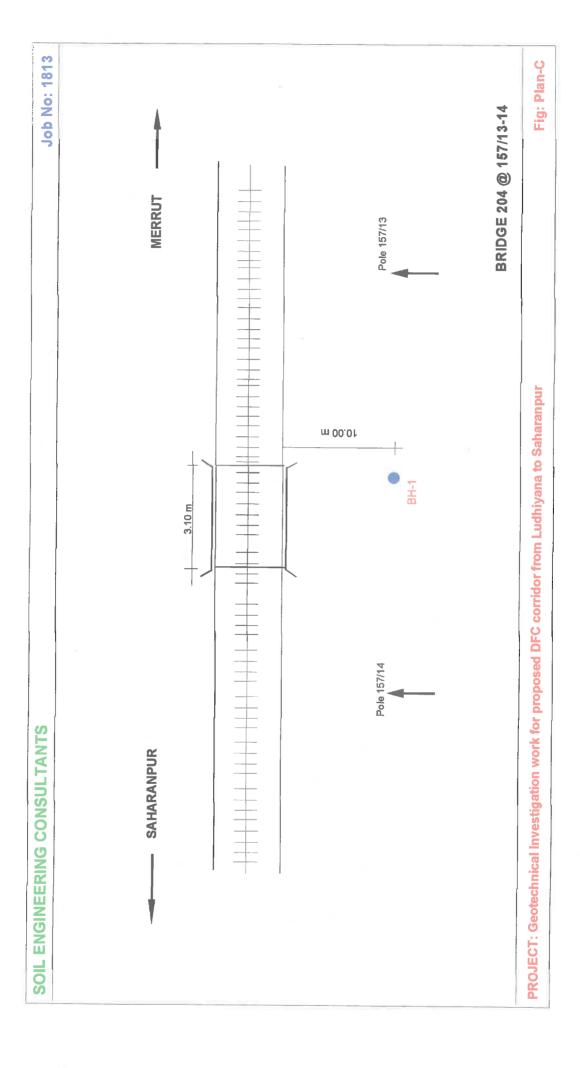
*34

12.00

SPT

247.650 12.30





Date of finish: 18/07/2008

Depth: 12.00 Depth of Water table: Not Met

RL: 259.060

204

Bridge

Project No. 1813

Location; 157/13-14 BH No.: 1

Date of start : 17/07/2008

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Cc Shear Parameters phi(degrees) 8 9 31 0.12 0.11 0.3 C(kg/sq.cm) DST DST DST Type of test 2.66 Sp.Gr Non Plastic Limits (%) J.4 TT W/C 11.79 12.32 (%)M 12.96 1.59 Density (gm/cc) 1.58 1,62 r(dry) 1.78 1.78 8 r(wet) Silt/clay 29 67 75 Grain size (%) 9 88 8 8 bas2 0 4 33 25 10 00 0 **Cravel** 0 0 0 0 N ---- 40 27 30 25 S.P.T Plot 00 Observed 20 5 10 1.00 2.00 3.00 4.00 5.00 00.9 2.00 8.00 00.6 10.00 11.00 Classification Sandy Silt with Gravel (SM-ML) Soil NDS UDS SPT SPT SPT SPT SON SPT SPT SPT Type of sample 1.80 2.50 3.30 4.80 5.50 6.30 7.80 8.50 9.30 Depth (m) 248.260 10.80 257.260 256.560 255.760 254.260 253.560 252.760 251.260 250.560 249.760 259.060 Reduced Level

3

0.15

DST

2.67

13.42

1.63

85

Non Plastic

73

27

0

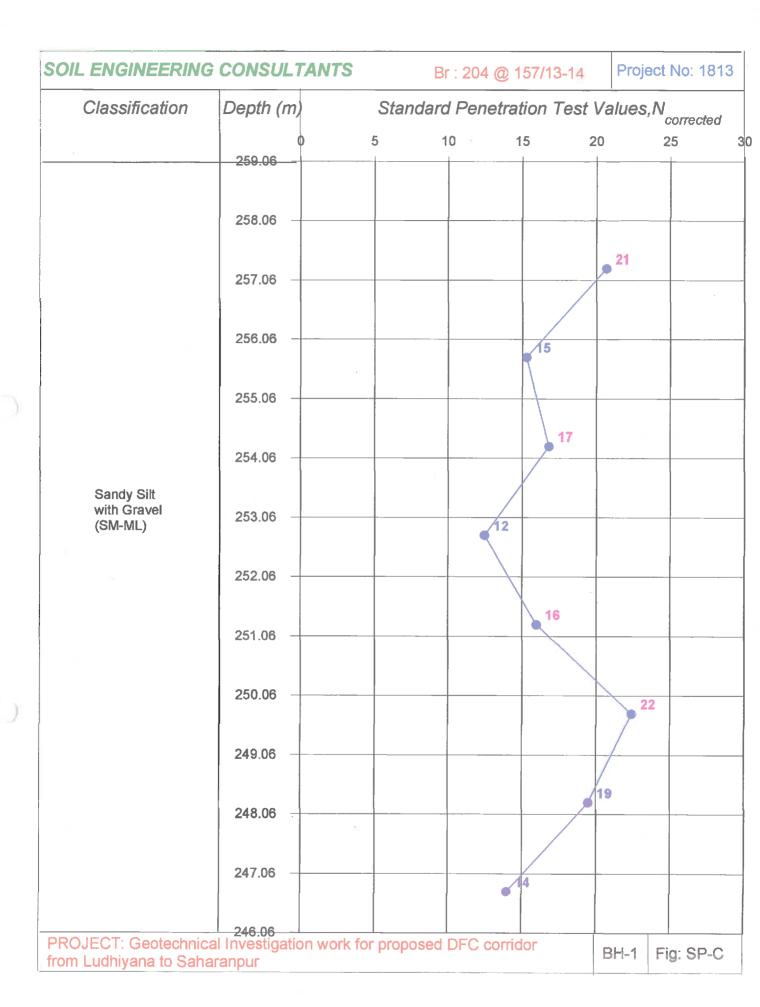
12,00

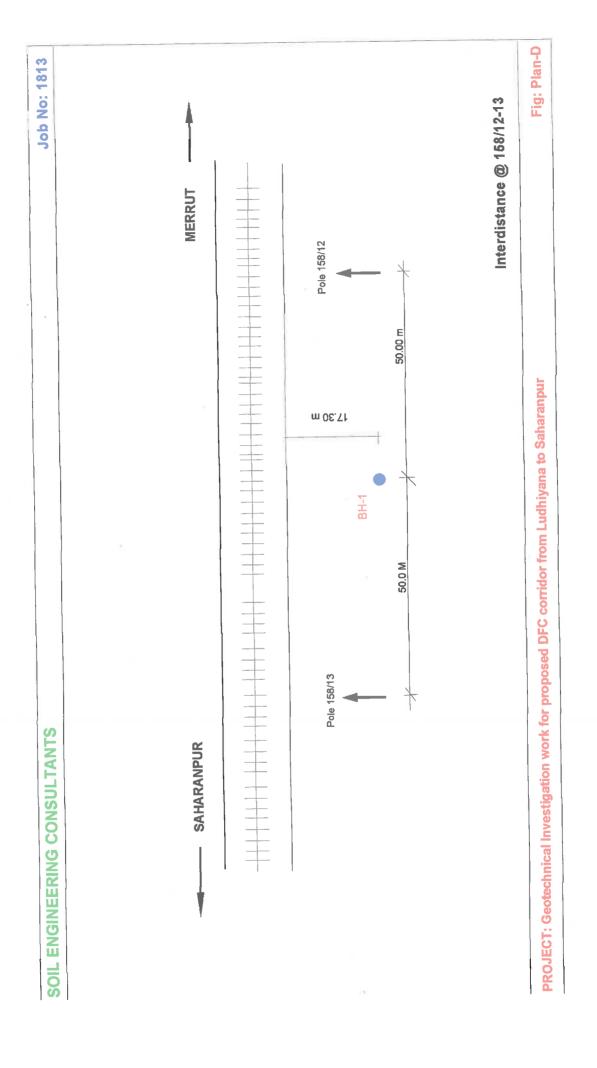
NDS

247.560 11.50

SPT

246.760 12.30





PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

RL: 259.060

Interdistance

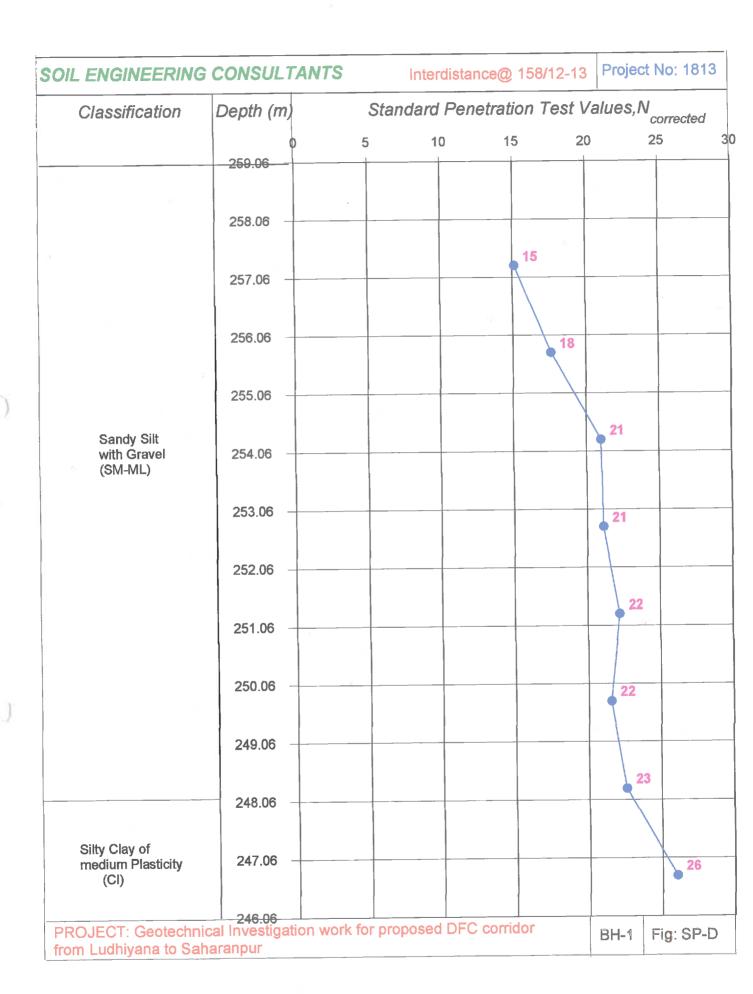
Project No. 1813

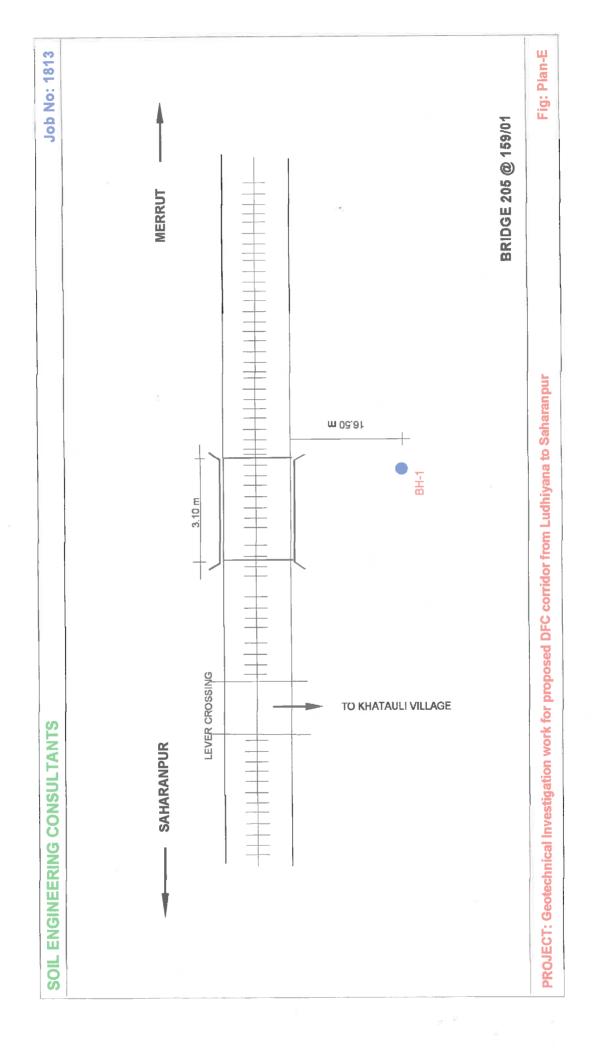
Location; 168/12-13
BH No.: 1
Depth: 12.00
Depth of Water table: Not Met

Date of finish Date of start

	ON PROMINERANG CORD
: 19/07/2008	: 19/07/2008

1		1		-													
	Cc																
eters	legrees))idq			30				32				32				
Shear Parameters	(wo·bs/	C(Kg			0.1				0.1				0.1			-	
Shear	test to a	Typ			DST				DST				DST		_		
	19.Gr	IS							2.65								-
Limits (%)	т.	d		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic	2
Limit	Т"	I		Non		Non		Non		Non	-	Non		Non		Non	39
W/C	(%)	M			11.92				11.96				13.42				
it.	(VTD	L(59				1.63				1.64		_		
Density	(Wet) (QTD)	IL(1.78				1.83	<u> </u>			1.86				
(%	t/clay	!S		91		78		9		 00 90		73				835	80
Grain size (%)	pue	S		9		22		<u></u>		34		56		9		<u>5</u>	0
Grai	ravel	C	_	ო		0		0		0		_		0		0	0
	30 35											10				k 29	(0
ot	0 25	_						k 20		* 22		* 25		* 26			* 26
T Plot	rved			*		* 15		· ·									
S.P.T	Observed			*													
3	0																
		80.00	1.00	2.00		3.00	4.00	5.00		00'9	7.00	8.00		9.00	10.00	11.00	12.00 -
	Soil Classification						Sandy Silt with Gravel	(SM-ML)									Silty Clay of medium Palsticity (CI)
əįdu	Type of sar	L		SPT	NDS	SPT		SPT	SON	SPT		SPT	SON	SPT		SPT	SPT
(u	Depth (1			1.80	2.50	3.30		4.80	5.50	6.30		7.80	8.50	9.30		08.0	2.30
[əлə	T bəənbəş	259.060 -		257.260	256,560	255.760		254.260	253.560	252.760		251.260	250.560	249.760		248.260 10.80	246.760 12.30
		Ň		_%_	12	_%		25				25	25	24		24	24(



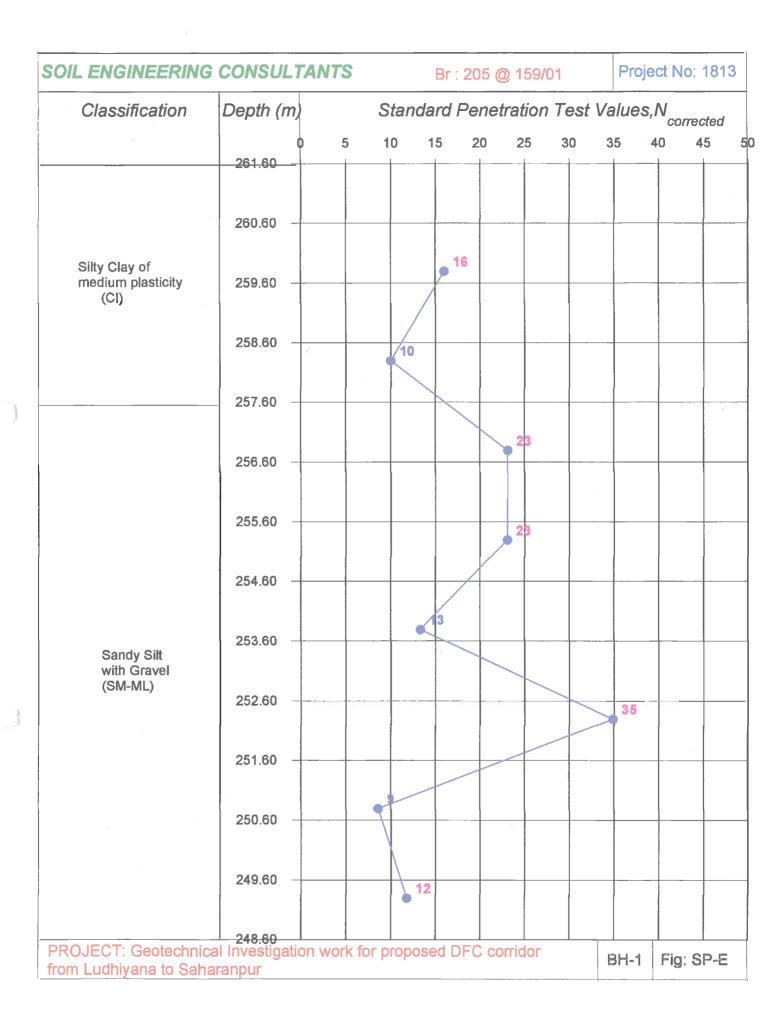


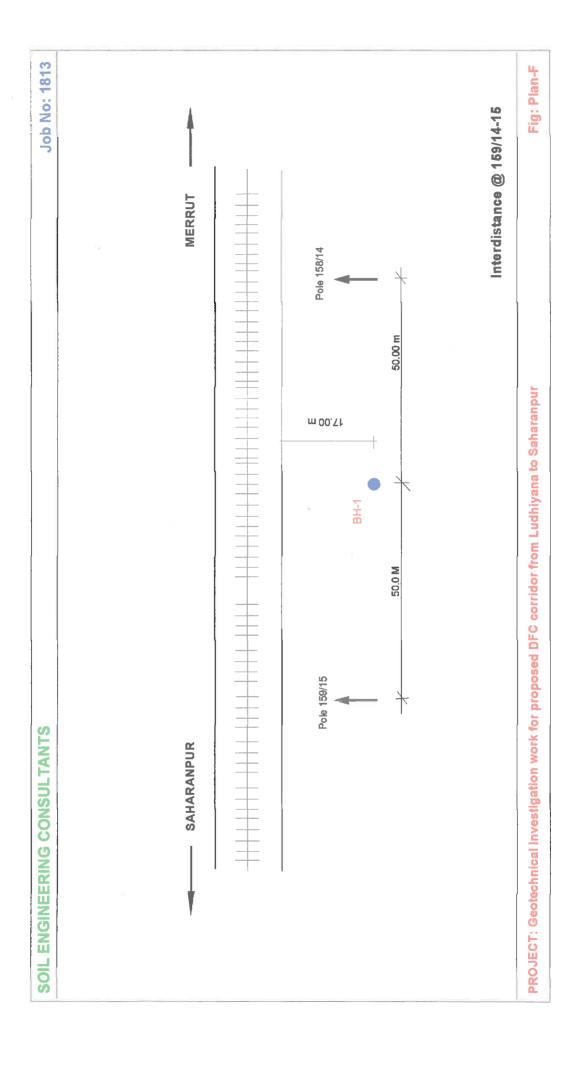
Date of finish: 20/07/2008 Date of start : 20/07/2008

PR o

Location;159/01 BH No.: 1	Depth: 12.00 Depth of Water table: Not Met
n work for proposed DFC corridor	RL: 261.598
nnical Investigation Saharanpur	Bridge : 205
ROJECT: Geotech om Ludhiyana to	roject No. 1813

T CHOOMERING CONSULT	Č				0.077												
T ANGORRER	Shear Parameters	phi(degrees)	E1		9				32				9				
Date of finish : 20/07/2008		(mɔ.pɛ/gx))			0.56				0.15				0.15				
		Type of test			n		- 1		DST				DST				
		Sp.Gr				_			2.65								
	Limits (%)	J. I		56		24		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic	Non Plastic
		ТТ		44		42		Non		Non		Non		Non		Non	Non
	W/C	(%)W	11.93				14.42				5.51						
	sity (cc)	r(dry)			1.61				1.65				1.63				
Not M	Density (gm/cc)	r(wet)	8.				1.89				88.						
Depth : 12.00 RL: 261.598 Depth of Water table : Not Met	Grain size (%)	Sik/clay		78		94		80		20		78		00		<u></u>	96
		base		00		ന		2		19		22		9		~	4
		Gravel		n		ო		0		0		0		-		0	0
	S.P.T Plot	30 40 50	-					22		k 24				* 42			
		Observed		* 16		*10		*				*15				¥-	*
		9		2.00		3,09	4.09	5.00		6.03	7.00	8.03		9.00	10.00	11.00	12.00
Bridge : 205 RL: 20	Soil Classification Sifty Clay of medium Plasticity (CI)						Sandy Silt with Gravel (SM-ML)										
Project No. 1813 Bridg	ambje	Type of sa		SPT	SQN	SPT		SPT	SON	SPT		SPT	SON	SPT		SPT	SPT
	(m)	Б ерth		1.80	2.50	3.30		4.80	5.50	6.30		7.80	8.50	9.30	-	10.80	12.30
Project	Isva.I	Reduced 5	080.107	259.798	259.098	258.298		256,798	256.098	255.298		253.798	253.098	252.298		250.798 10.80	249.298 12.30





Location; 159/14-15 BH No.: 1

PROJECT: Geotechnical Investigation work for proposed DFC corridor

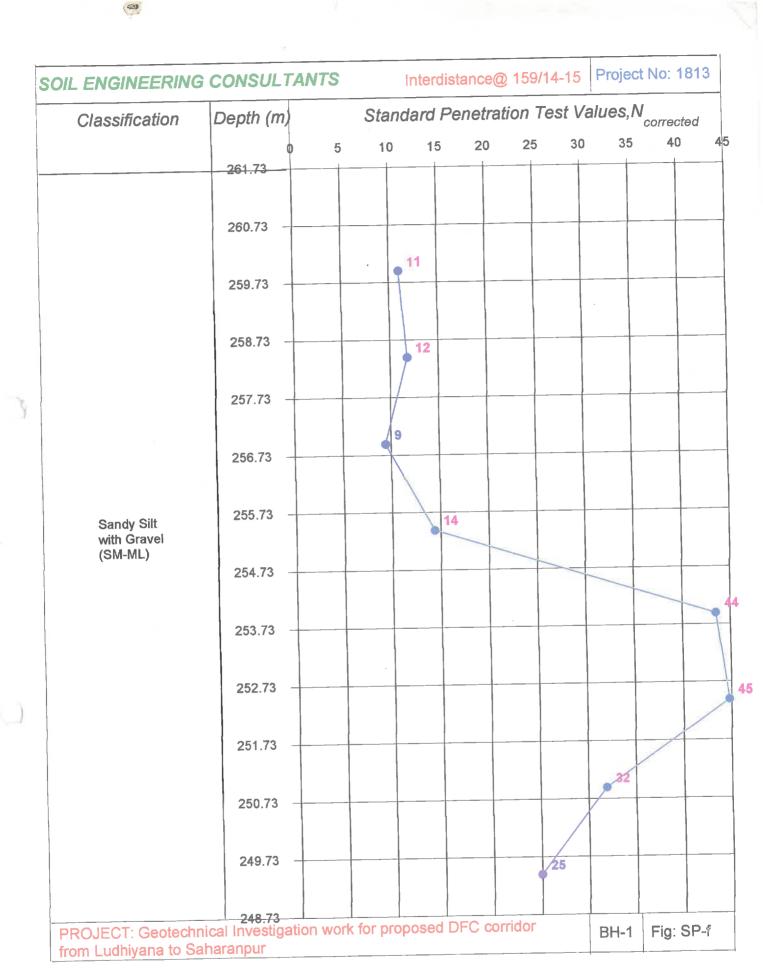
from Ludhiyana to Saharanpur

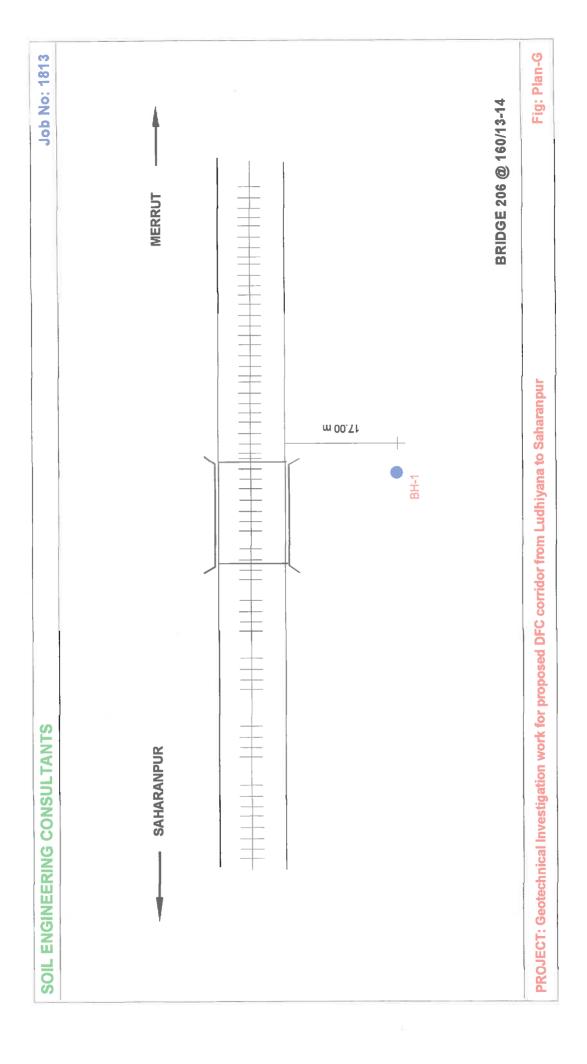
Interdistance

Project No. 1813

Date of start : 21/07/2008 Date of finish: 22/07/2008

Cc (degrees) Shear Parameters 29 29 C(kg/sq.cm) 0.1 0.1 DST DST Type of test 2.65 Sp.Gr Non Plastic Limits (%) P.L TT W/C 12.69 14.45 (%)M 1.59 1.56 Density (gm/cc) r(dry) Depth: 12.00 Depth of Water table: Not Met 1.79 1.79 r(wet) Silt/clay 86 8 Grain size (%) <u>~</u> 8 8 82 71 79 N Sand N 9 0 $\frac{7}{2}$ 28 2 **Cravel** 0 0 7 0 $^{\circ}$ 0 09 54 50 4 40 *34 S.P.T Plot Observed 30 20 9 00 10 RL: 261.726 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 II.00 9.00 12.00 10.00 Classification Sandy Silt with Gravel (SM-ML) NDS SPT SPT NDS SPT SPT SPT SPT SPT SPT Lype of sample 1.80 2.50 3.30 4.80 Depth (m) 5.50 6.30 7.80 9.30 249.426 12.30 250.926 10.80 259.926 259.226 258.426 256.926 256.226 261.726 255.426 253.926 252.426 Reduced Level





PROJECT: Geotechnical investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

RL: 259.869

Bridge: 206

Project No. 1813

S.P.T Plot

00 -

20

40

30

20

10

Classification

Soil

Lype of sample

Depth (m)

Reduced Level

259,869

Observed

1.00

2.00

SON

2.50

257.369

SPT

3.30

256,569

SPT

1.80

258.069

3.00

4.00

5.00

6.00

Sandy Silt with Gravel (SM-ML)

UDS

5.50

254.369

SPT

6.30

253.569

SPT

4.80

255.069

7.00

22

8.00

SPT

7.80

252.069

00.6

SPT

9.30

250.569

10.00

4

Location;160/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of finish : 23/07/2008

Date of start :: 23/07/2008

	သ						_
eters	phi(degrees)	C	P.	Ç	9		
Shear Parameters	C(kg/sq.cm)	C 7	<u>e</u>	C TI	0		
Shear	Type of test	F C		F 0	8		
	Sp.Gr	0	0.7				
Limits (%)	P.L	Non Plastic					
Limit	ТТ	Non	Non	Non	Non	Non	Non
W/C	(%)M	200	2	7	<u>†</u>		
Density (gm/cc)	r(dry)	2	5	3	8		
Der (gr	r(wet)	1 84		or C	2		_
(%)	Silt/clay	 94	06	80	00	8	87
Grain size (%)	Sand	 4	_	0	_	~	6
Gra	Cravel	N	ო	0	0	0	0

Non Plastic

8

9

0

32

11.00

SPT

249.069 10.80

Non Plastic

94

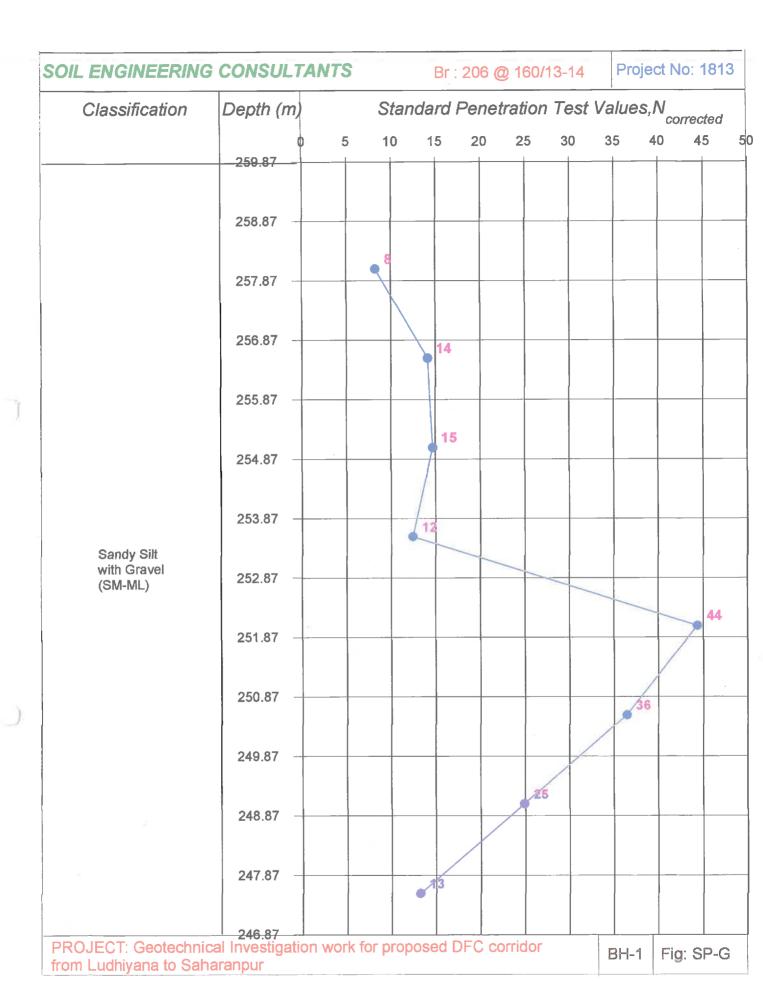
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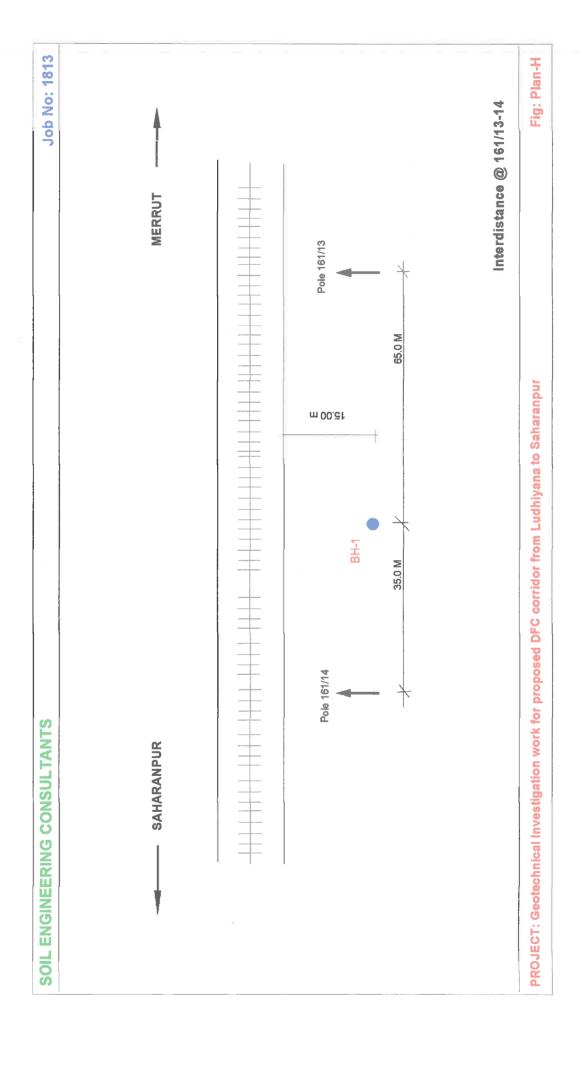
*18

12.00

SPT

247.569 12.30





PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Interdistance

Project No. 1813

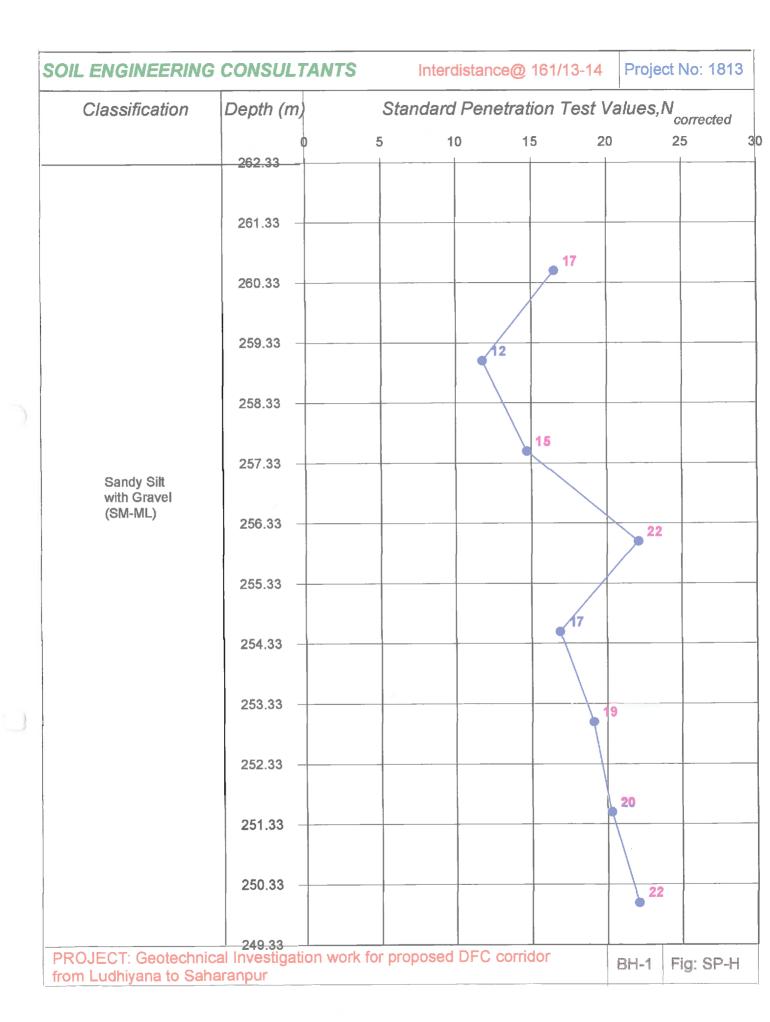
Location; 161/13-14 BH No.: 1 Depth : 12.00 Depth of Water table : Not Met

Date of start : 24/07/2008

Date of finish: 24/07/2008

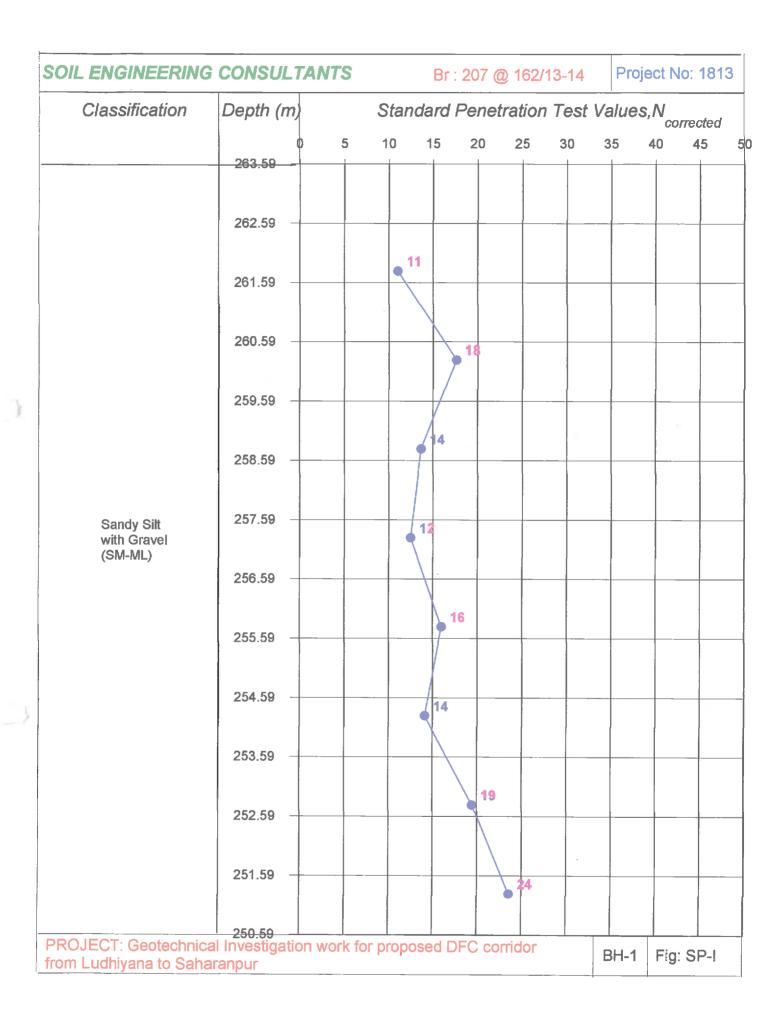
RL: 262.330

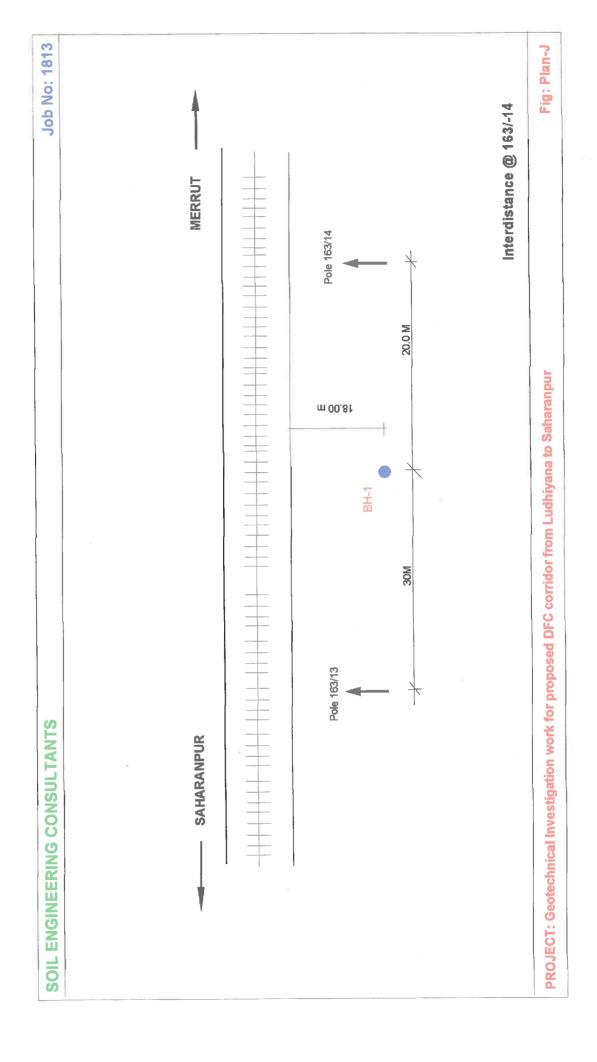
	Ce															
eters	(essrees)			29				30				32				
Shear Parameters	C(kg/sq.cm)			0.1				0.15			-	0.18				-
Shear	Type of test			DST				DST			_	DST				
	Sp.Gr							n i								
Limits (%)	J.4		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic	Non Plastic
Limit	ТТ		Non		Non		Non		Non		Non		Non		Non	Non
W/C	(%)M			11.84				12.43				13.61				
Density (gm/cc)	r(dry)			1.60				1.62				1.64				
Der (gr	r(wet)			1.79				1.82				1.86				
(%)	Silt/clay		94		92		26		87		00		26		98	84
Grain size (%)	Sand		4		ဖ		ო		Ø		12		ო		2	16
Grai	Gravel		7		8		0		4		0	*	0		0	0
	50															
t t	40															k 30
Plot	ved						_		* 23		6		*23		*28	*
S.P.T	Observed		* 12		2		* 14				*					
-	0 -	-			-				_							
	90	I.00	2.00		3.00	4.00	5.00		6.00	7.00	8.00		9.00 —	10.00	11.00 —	12.00
	Soil							Sandy Silt	with Gravel (SM-ML)							
ambje	Type of sa		SPT	SON	SPT		SPT	SON	SPT		SPT	SQN	SPT		SPT	SPT
(w)	Depth		1.80	2.50	3.30		4.80	5.50	6.30		7.80	8.50	9.30		08.01	2.30
I9v9.I	Reduced		260.530	259.830	259.030		257.530	256.830	256.030		254.530	253.830	253.030		251.530 10.80	250.030 12.30



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

PROJECT: Geotechnical Investigation work for proposed from Ludhiyana to Saharanpur	Project No. 1813	(m)	Depth	763,383	261.785 1.80 8	261.085 2.50 L	260,285 3,30 8		258.785 4.80 8	258.085 5.50 L	257.285 6.30 8		255.785 7.80 8	255.085 8.50 L	254.285 9.30		252.785 10.80 8	252.085 11.50 L	
ical Investigation aharanpur	Bridge: 207	umbje	Soil Classification	Sandy Silt with Gravel	SPT (SM-ML)	SON	SPT		SPT Silty Sand	(SM) SQU	LdS		SPT	nDs	SPT TAS	with Gravel (SM-ML)	SPT	Sau	i i
work fo	RL: 263,585		ation	Silt	<u>[]</u>				bul						±	avel			
r propos	3.585		0	1.60	2.00		3.00	4.00	5.00		6.00	7.00	8.00		00.6	10.00	11.00		12.00
ed DFC corridor	:	S.P.T Plot	Observed		*		* 15		* 13		*13		* 18		* 11		*		
Loca	0 0		30 40														25		***************************************
Location; 162/13-14 BH No.: 1	Depth of Water table: Not Met	Grai	Gravel		_		0		0		0		_		0		0		_
62/13-	ater ta	Grain size (%)	bas2		4		53		59		78		56		4		47		Ö
4	Die : N		Silt/clay		92		47		14		8		73		9		53		09
	ot Met	Density (gm/cc)	r(wet)			1.76				1.8				1.83				1.87 1.	
			r(dry)			1,55				1.57 1				1,57 16				1.58	
		W/C	(%)W			13.81				14.62				16.86				18.20	
Ω		Limits (%)	T.I.		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic
te of sta	te of fini		Sp.Gr		dic		÷ i		ţį	2,66	Ę.	_	fic	2.66	Ę.		<u>_</u>		
Date of start : 27/07/2008	Date of finish : 27/07/2008	Shea	Type of test			DST				DST		_		DST				DST	
07/2008	07/2008	Shear Parameters	C(kg/sq.cm)			0.15				0.1				0.1				0.1	
V,	SWEHLERING C	neters	(degrees)			53				8			<u> </u>	8				31	
	RING COMSUM		Ö																





PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

RL: 265.670

Interdistance

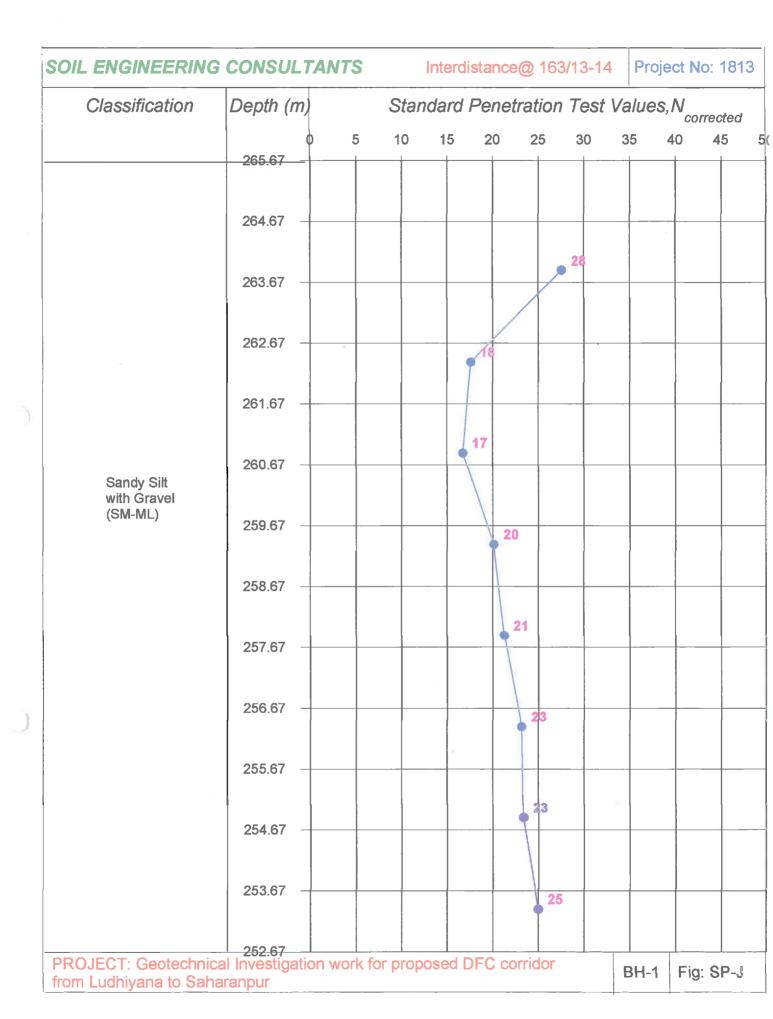
Project No. 1813

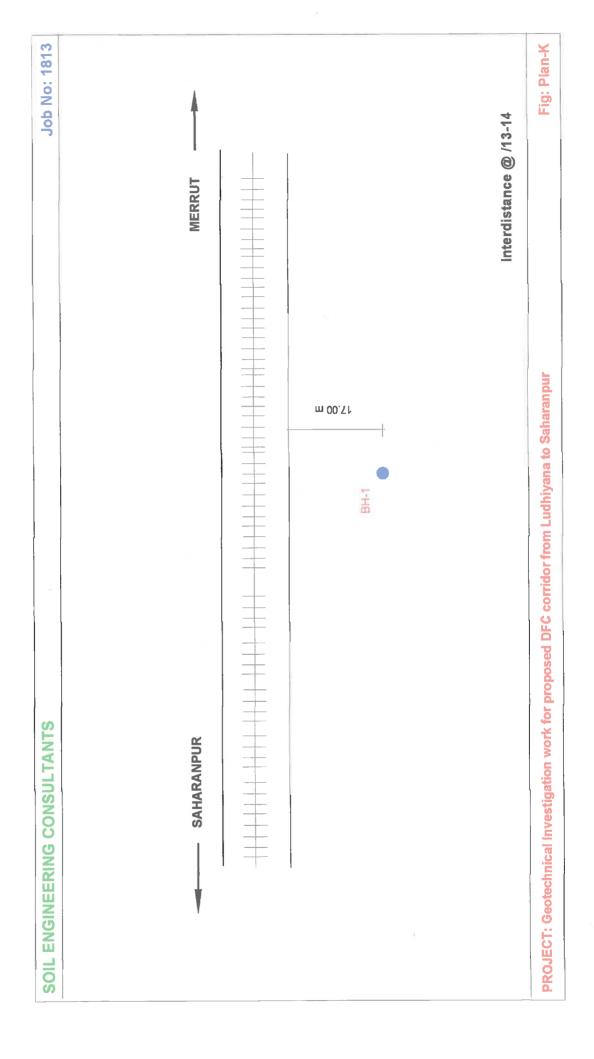
Location; 163/13-14 BH No.: 1 Depth : 12.00 Depth of Water table : Not Met

Date of start : 25/07/2008

Date of finish: 26/07/2008

	Cc													
eters	phi(degrees)		34				32				32			1
Shear Parameters	C(kg/sq.cm)		0.1		_		0.1		-		0.1			
Shear	rset to sqyT		DST				DST				DST			
	Sp.Gr						2.66				2.66			
Limits (%)	J.4	Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic	Non Plastic	Non Plastic
Limit	TT	Non		Non		Non		Non		Non		Non	Non	Non
W/C	(%)M		10.43				12.61				13.78			
Density (gm/cc)	r(dry)		1.63				1.63				8.			
Der (gr	r(wet)		<u>τ</u> ∞				1.83		_		1.86			
(%)	Silt/clay	92		96		61		95		99		97	95	8
Grain size (%)	base	ന		n		30		5		34		ო	4	9
Grai	Cravel	7		_		0		0		0		0	~	4
S.P.T Plot	Observed 0 10 20 30 40 50 50 70 80 90 100 110 120	*20		*15		*16		*21		*24		*28	*30	*34
	Soil Classification						Sandy Silt with Gravel	(SM-ML)						
əլdun	Type of sa	SPT	SON	SPT		SPT	SON	SPT		SPT	SON	SPT	SPT	SPT
(m)	Depth (1.80	2.50	3.30		4.80	5.50	6.30		7.80	8.50	9.30	10.80	12.30
[əvə/]	Reduced 1	263.870	263.170	262.370		260.870	260.170	259.370		257.870	257.170	256.370	254.870 10.80	253.370 12.30





PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Interdistance

Project No. 1813



09

20

40

30

20 10

Classification

Type of sample

Depth (m)

***** 32

Sandy Silt with Gravel (SM-ML)

7

Silty Sand with gravel (SM)

SPT

3.30

263.145

UDS

2.50

263.945

SPT

1.80

264.645

20

UDS

5.50

260.945

SPT

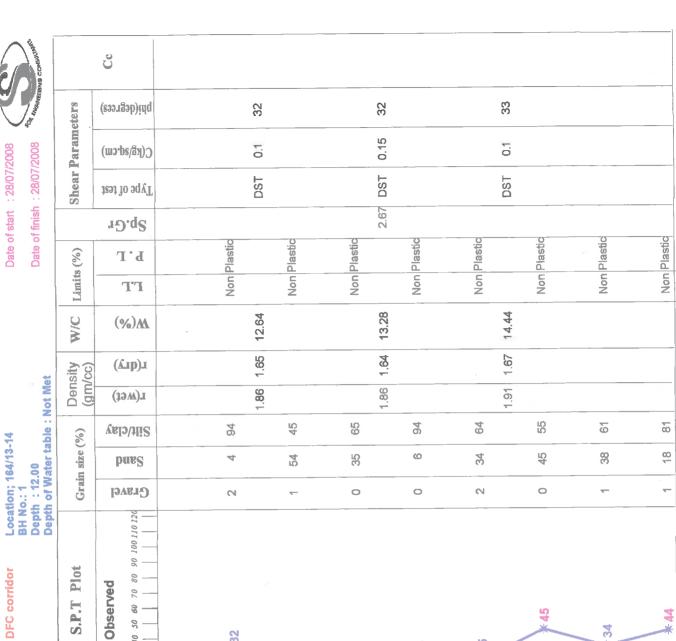
4.80

261.645

SPT

6.30

260.145



45

25

Sandy Silt with Gravel (SM-ML)

SPT

7.80

258.645

NDS

8.50

257.945

SPT

9.30

257.145

24

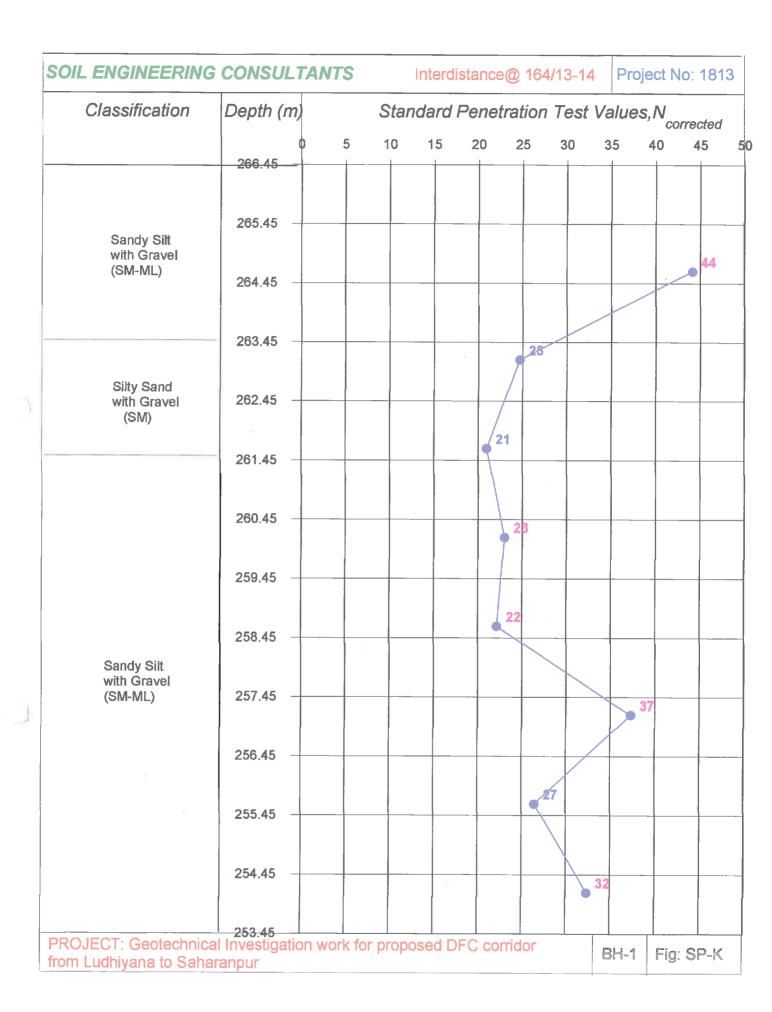
34

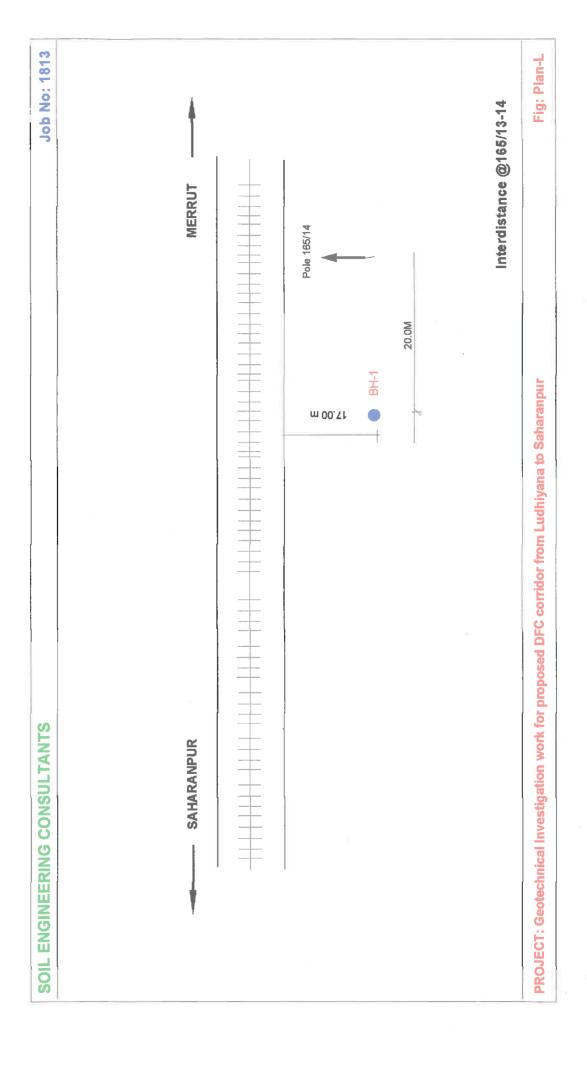
SPT

255.645 10.80

SPT

254.145 12.30





PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhlyana to Saharanpur

RL: 269.060

Interdistance

Project No. 1813

Lype of sample

Depth (m)

Reduced Level

Location; 165/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of finish : 30/07/2008

Date of start : 29/07/2008

	ů						
eters	phi(degrees)		30		30	(32
Shear Parameters	C(kg/sq.cm)		0.1		0.1	Į.	0.70
Shear	Type of test		DST		DST	1	20
	Sp.Gr				2.66		
Limits (%)	J.4	Non Plastic	Non Plastic	Non Plastic	Non Plastic	Non Plastic	Non Plastic
Limit	FT	No	Non	Non	Non	No	Non
W/C	(%)M		12.87		1.4 1.4	!	15.43
sity (cc)	r(dry)		1.62		26.	!	1.62
Density (gm/cc)	r(wet)	-	1.83		1.84		78.
(%)	Silt/clay	96	20	84	78	80	58
Grain size (%)	purs	ω	00	52	22	17	42
Grai	Cravel	0	_	0	0	0	0
.P.T Plot	Observed 0 10 20 30 40 50 60 70 80 90 10 01 10 20				± 50	30	26
Š	Ob 10 20 3	* 10	*	* 12	*		1
	0	J.00	3.00	4.00	6.00	3.00	9.00
	Soil Classification	Sandy Silt with Gravel		Silty Sand (SM)	v	Sandy Silk	with Gravel (SM-ML)
i .							

Non Plastic

89

3

Non Plastic

80

2

0

34

11.00

SPT

258.260 10.80

12.00

SPT

256.760 12.30

10.00

SON

8.50

260.560

SPT

9.30

259.760

SPT

261.260

UDS

2.50

266.560

SPT

267.260

SPT

3.30

265.760

NDS

5.50

263,560

SPT

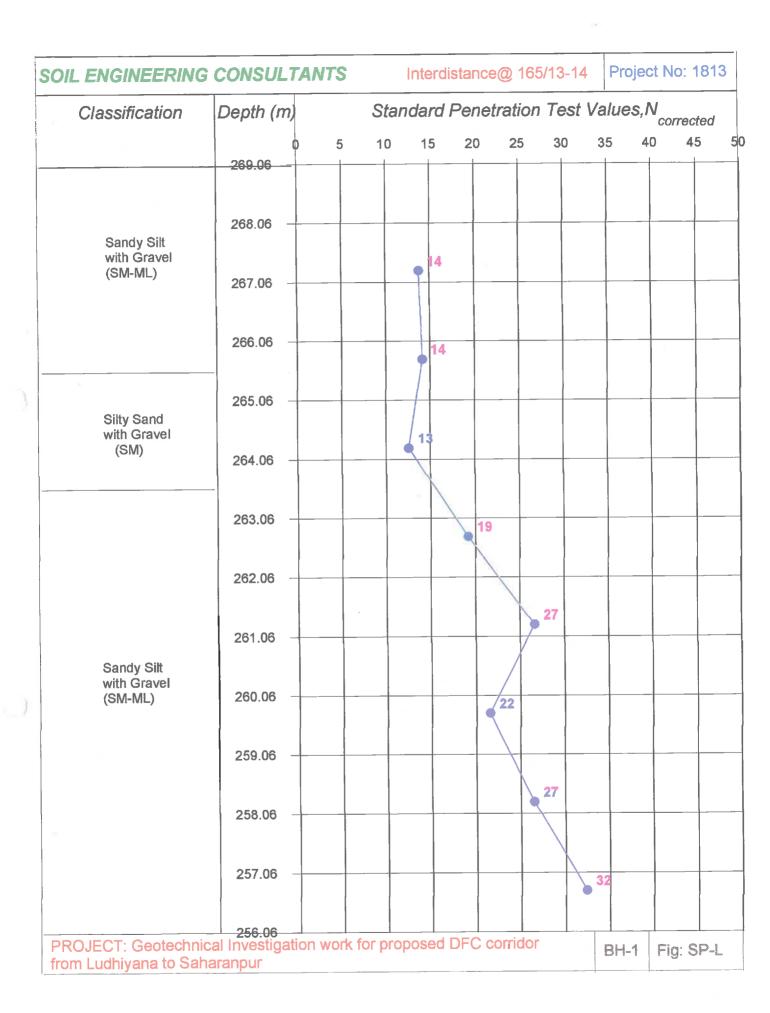
6.30

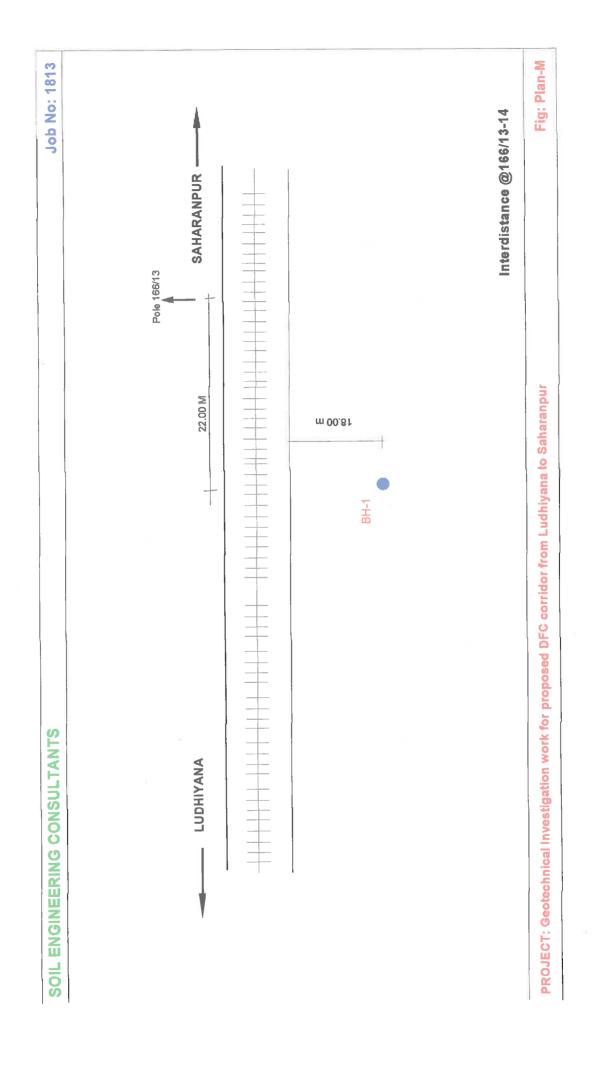
262.760

SPT

4.80

264.260





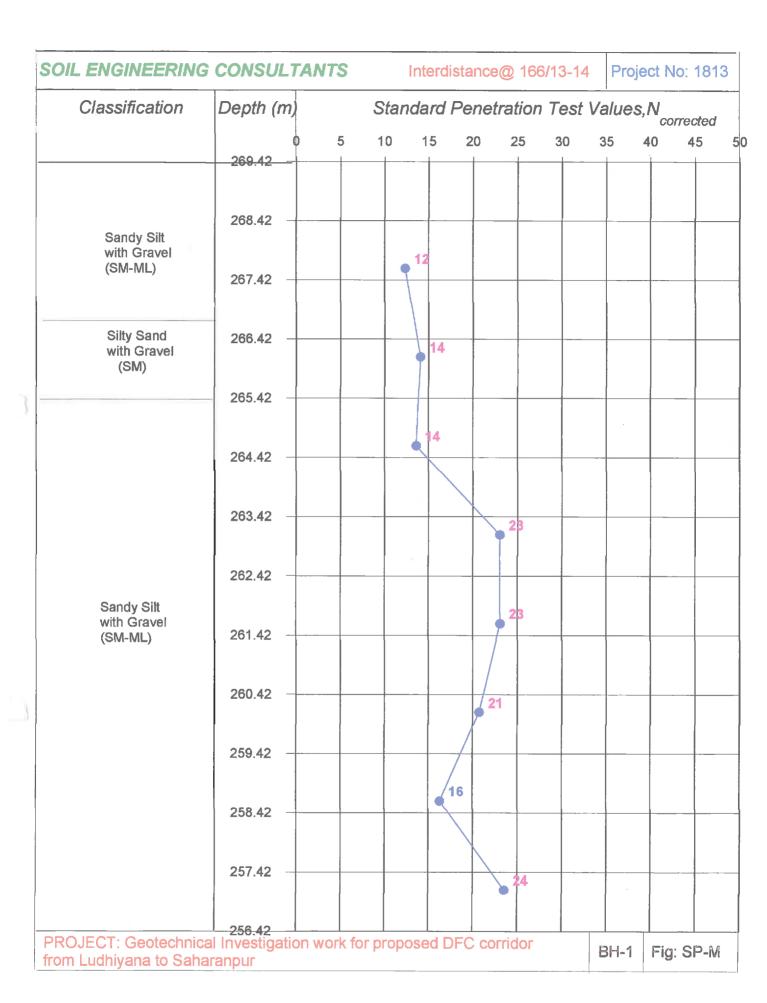
PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Location; 168/13-14
BH No.: 1
Depth: 12.00
Depth of Water table: Not Met

Date of finish : 02/08/2008

Date of start : 01/08/2008

MENERING CONSUST		ů															
SACONTER.	eters	(essrees)			30				32				32				
8008	Parameters	С(кg/sq.cm)		-	0.15				0.1				0.1				
Date of finish : 02/08/2008	Shear	Type of test		-	DST				DST				DST				
tinish		Sp.Gr							2.66				2.65				
Date of	(%) s	P.L		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic	_	Non Plastic		Non Plastic	Non Plastic
	Limits (%)	ΓT		Non		Non		Non		Non		Non		Non		Non	Non
	W/C	(%)M			12.87				14.11				15.47	_			
#	sity (cc)	r(dry)	-		1.58				1.61				1.64				
lot Me	Density (gm/cc)	r(wet)			1.78				1.84				1.89				
ble : N	(%)	Silt/clay		92	_	46		71		46		09		7.1		99	52
ater ta	Grain s 5e (%)	E		00		53		8		9		40		29		34	89
Depth of Water table: Not Met	Grain	Cravel		0		_		0		0		0		0		0	0
Deg	S.P.T Plot	Observed 0 10 20 30 40 50 60 70 80 9010@1@20		о *		*12		* 13		*24		* 26		*25		*21	*32
0		99		1.00 — 2.00 —		3.00	4.00	5.00		6.00	7.00	8.00		00.6	10.00	11.00 —	12.00 —
Interdistance RL: 269.420		Soil Classification		Sandy Silt with Gravel (SM-ML)		Silty Sand with gravel	(NIC)					Sandy Silt	(SM-ML)				
	əլdun	Type of sa		SPT	SQN	SPT		SPT	SON	SPT		SPT	SQN	SPT		SPT	SPT
>. 1813	(w)	Depth		1.80	2.50	3.30		4.80	5.50	6.30		7.80	8.50	9.30		10.80	2.30
Project No. 1813	[9və/]	Reduced	269.420	267.620	266.920	266.120		264.620	263.920	263.120		261.620	260.920	260.120		258.620 10.80	257.120 12.30



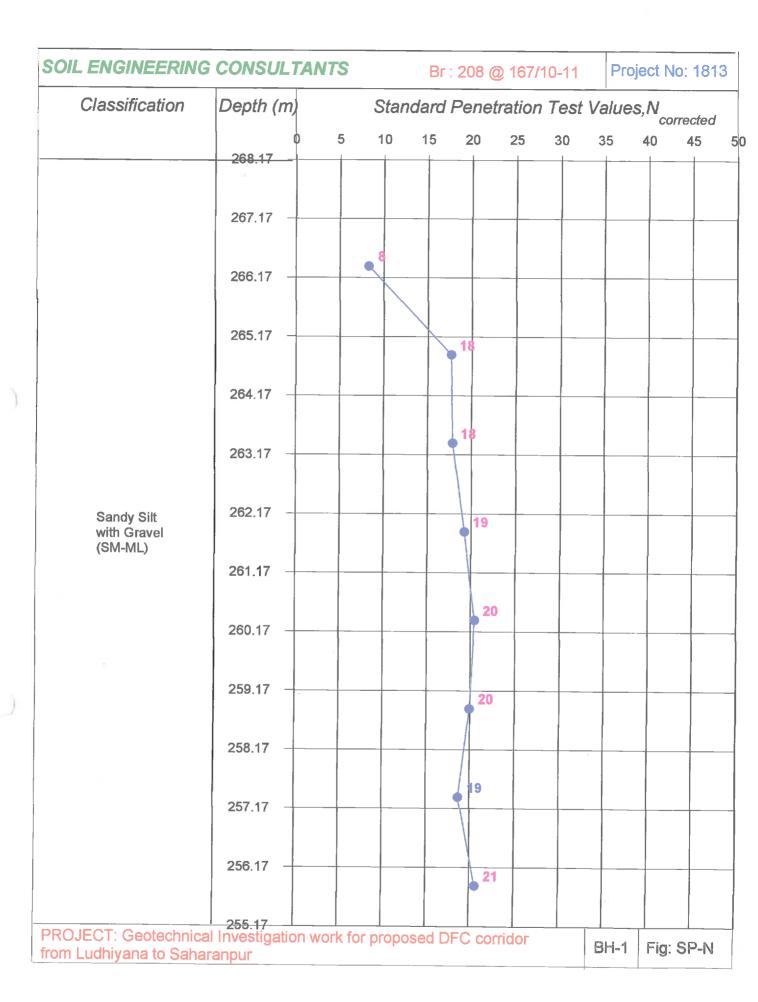
PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

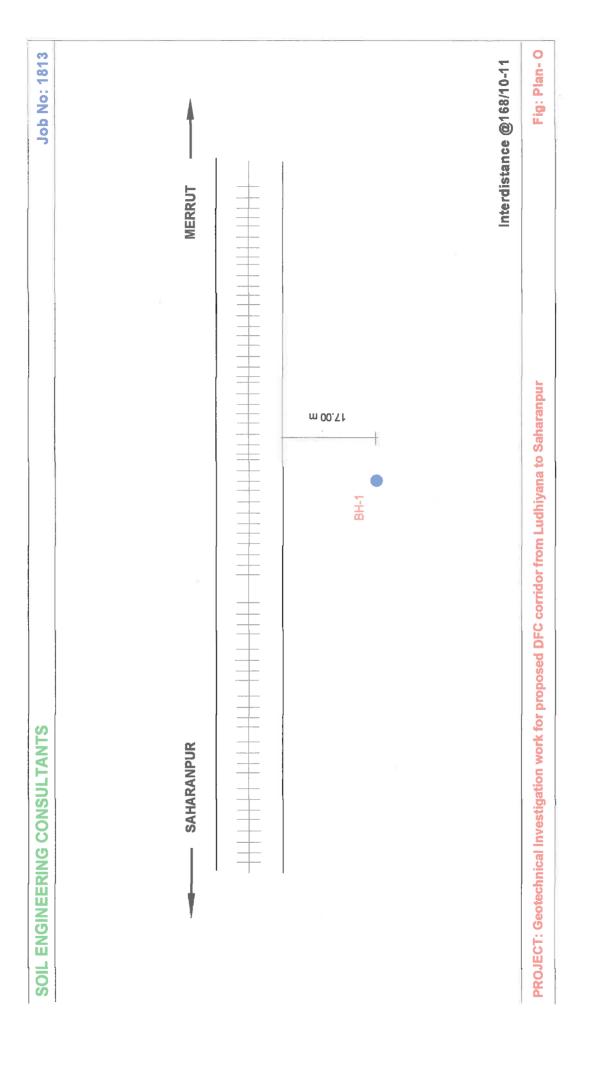
Location; 167/10-11 BH No.: 1 Depth: 12.00 Depth of Water table: Not Met

Date of start : 02/08/2008

Date of finish: 03/08/2008

MENNE CONSULT		Š																
A PACCOVETER	eters	(eserges)				29				32				32			_	
	Parame	(kg/sq.cm)		-		0.1		-		0.1				0.15				
Date of finish: 03/08/2008	Shear Parameters	Type of test				DST				DST				DST				
of finish		Sp.Gr								2.66							-	
Date o	(%) s	P.L			Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic		Non Plastic	Non Plastic
	Limits (%)	rr			Non		Non		Non		Non		Non		Non		Non	Non
	W/C	(%)M				11.89				13.42				15.61				
44	sity (cc)	r(dry)				1.55				1.64				1.62				
Depth : 12.00 Depth of Water table : Not Met	Density (gm/cc)	r(wet)				1.73				1.86		-		1.87				
able:	(%)	Silt/clay			92		83		54		73		9		72		80	83
.00 Vater t	Grain size (%)	Sand			ო		17		46		27		4		28		12	17
th : 12 th of V	Gra	Gravel			7		0		0		0		~		0		0	0
Dep		40																00
	Plot	30									20		* 23		* 24		* 24	* 78
		Observed	-				* 15		*									
	S.P.T	Observe 100			*													
3.168		0 —	8.96	1.06	2.00		3.00	4.00	5.00		0.00	7.06	8.00		9.00	10.00	11.00	12.00
Bridge : 208 RL: 268.168		Soil Classification								t le	(SM-ML)					H	Prod	I
	nubje	Type of s			SPT	SON	SPT		SPT	SON	SPT		SPT	NDS	SPT		SPT	SPT
5. 1813	(w)	Depth			1.80	2.50	3.30		4.80	5.50	6.30		7.80	8.50	9.30		0.80	2.30
Project No. 1813	[9v9.]	Reduced	268.168	_	266.368	265.668	264.868	· ·	263.368	262.668	261,868		260,368	259.668	258.868		257.368 10.80	255.868 12.30





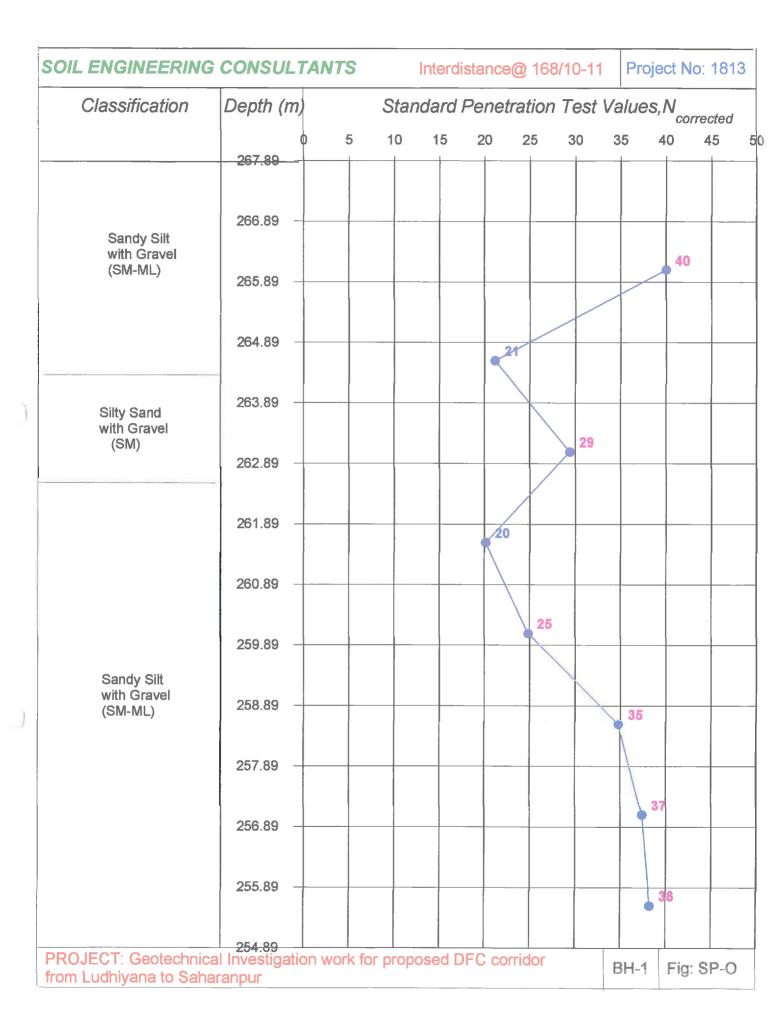
PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Location; 168/10-11 BH No.: 1 Depth : 12.00 Depth of Water table : Not Met

Date of start : 03/08/2008

Date of finish: 04/08/2008

Project No. 1819 Parameter	a [
Type of 'sample Classification Constituent table : Not Mate	BING CONE		သိ														
Type of sample Soil	CNOWEE	eters	(degrees)			31			32				33				
Type of sample Chassification Soil Chassification Soil Chassification Soil Chassification	200	Paramo	C(kg/sq.cm)			0.15			0.1				0.1		-		
Type of sample Non Plastic	04/US/Z	Shear	Type of test			DST	_		DST				DST				
Type of sample Soil	: usiuii	92	Sp.Gr		-				2.65								
Type of sample Soil	Date or	(%)	J.4		Plastic		Plastic	Plastic	-	Plastic		Plastic		Plastic		Plastic	Plastic
Type of sample Soil Soil Soil Soil Soil Soil Sandy Sitt Sandy Sit		Limits	ТТ		Non		Non	Non		Non		Non		Non		Non	Non
Type of sample S.P.T Plot Crain size (%) Classification Classifi		W/C	(%)M			11.93			12.47				13.21				
Type of sample Spil Observed Classification Spil Observed Classification Spil Observed Classification Sandy Silt 1.00 2.00	*	sity (cc)	r(dry)			1.66			1.72				1.73				
Interdistance RL: 267.890 S.P.T Plot Soil Observed Classification Observed Classification Observed Soil Sandy Silt With Gravel SPT Sandy Silt Sandy Silt SPT	Not Me	Den (gm	r(wet)			1.86		4.00	1.93				1.96				
Interdistance RL: 267.890 S.P.T Plot Soil Observed Classification Observed Classification Observed Soil Sandy Silt With Gravel SPT Sandy Silt Sandy Silt SPT	able :	(%)	Silt/clay		92		80	84		89		91		74		61	88
Interdistance RL: 267.890 S.P.T Plot Soil Observed Classification Observed Classification Observed Soil Sandy Silt With Gravel SPT Sandy Silt Sandy Silt SPT	Vater t	in size	bars		4		7	52		32		თ		26		33	=
Interdistance RL: 267.890 S.P.T Plot Soil Observed Classification Observed Classification	th of V	Gra	-		~		0	0		0		0		0		0	0
Soil Soil Soil Soil Sandy Sitt with Gravel SPT (SM-ML) Sww SPT (SM) Sandy Sitt with Gravel SPT (SM) Sww SPT (SM) Sandy Sitt with Gravel SPT (SM) Sandy Sitt with Gravel SPT (SM-ML) SPT (SM-ML) SPT (SM-ML) 11.00 SPT SPT (SM-ML)	O C		9010011012														,
Spy Soil Soil Soil Sandy Sitt with Gravel SPT (SM-ML) Seril SPY (SM-ML) Seril SPY (SM-ML)		Plot	ed 60 70 80											2		8	52
Spy Soil Soil Soil Sandy Sitt with Gravel SPT (SM-ML) Seril SPY (SM-ML) Seril SPY (SM-ML)		P.T.	bserv		* 29		0	* 28				*28		*		*	
Sendy Sitt with Gravel SPT Selly Sand with Gravel SPT Silty Sand with Gravel SPT SILT Sendy Sitt with Gravel SPT SILT SEND SEND SEND SEND SEND SEND SEND SEND	890	01	0 10 20		1 1		*			*				1			
Sandy Sitt with Gravel SPT Sandy Sitt with Gravel SPT SILLy Sand with Gravel SPT SILLy Sand with Gravel SPT SILLy Sand with Gravel SPT	RL: 267.		8		1.00		3.00 —	4.00 —		6.00	7.00	8.00		9.00 —	10.00 —	11.00 —	12.00 —
S S S S S S S S S S S S S S S S S S S			Soil Classification		Sandy Silt with Gravel (SM-ML)			Silty Sand with gravel (SM)					Sandy Silt	(SM-ML)			
Project No. 1813 267.890 268.590 268.590 268.590 268.590 268.590 268.590 269.390 269	Inter	nubje	Type of sa		SPT	SGN	SPT	FPR	SON	SPT		SPT	SON	SPT		SPT	SPT
Project N. 267.28	. 1813	(w)	Depth		1.80	2.50	3.30	4.80	5.50	6.30		7.80	8.50	9.30		0.80	2.30
	Project No	[9v9.]	Keduced	707												257.090 1	255.590 1



CHAPTER - 24

"Alignment",

Location - Existing Km. - 174/450



24.1 LOCATION OF STRUCTURE:

Alignment at Existing Km. 174/450

24.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 8.00m below EGL

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 4.50	Silty Sand	Loose
D11 1	4.50 to 12.00	Silty Sand	Medium Dense

24.3 CHEMICAL ANALYSIS OF SOIL:

BORI	EHOLE		Cl	HEMICAL I	PROPERTII	ES	
No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity
	(m)	_		%	º/o	%	%
BH-1	3.00	8.20	NIL	0.0017	NIL	0.0011	0.008
<i>D</i> 11-1	6.00	8.30	NIL	0.0019	NIL	0.0012	0.011

24.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
•	6.00	NIL

24.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

	-11	Chloridae	C-1-1-1				KON DOI		
	pН	Chlorides				Acidity	Alkalinity	Total	Conducti
Chemical	Value	mg/lit	mg/lit	Matter	Matter	(ml)	(ml)	Disso.	vity
Properties				mg/lit	mg/lit		. ,	Solids	(µS/cm)
							L	(ppm)	
Test	6.4	118	116	149	659	0.1	2.8	808	1293
Result									
Requirement	Not	2000 for	400	200	3000	5 ml of	25 ml of	-	-
asper 15:456	less	CC and				0.02	0.02		
/ Mosrth's	then	500 for				normal	normal		
	6.0	RCC				NaoH	H ₂ SO ₄		

24.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	08.00
BH-1	- 3.00	14.00
	4.50	16.00
	6.00	17.50

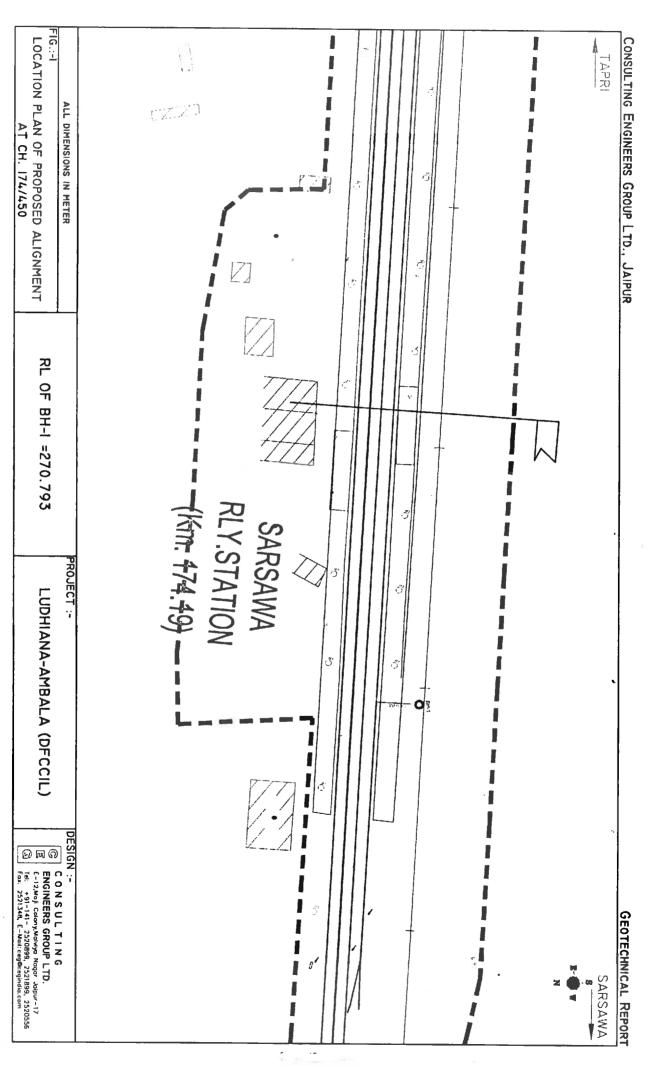
24.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

24.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 3.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

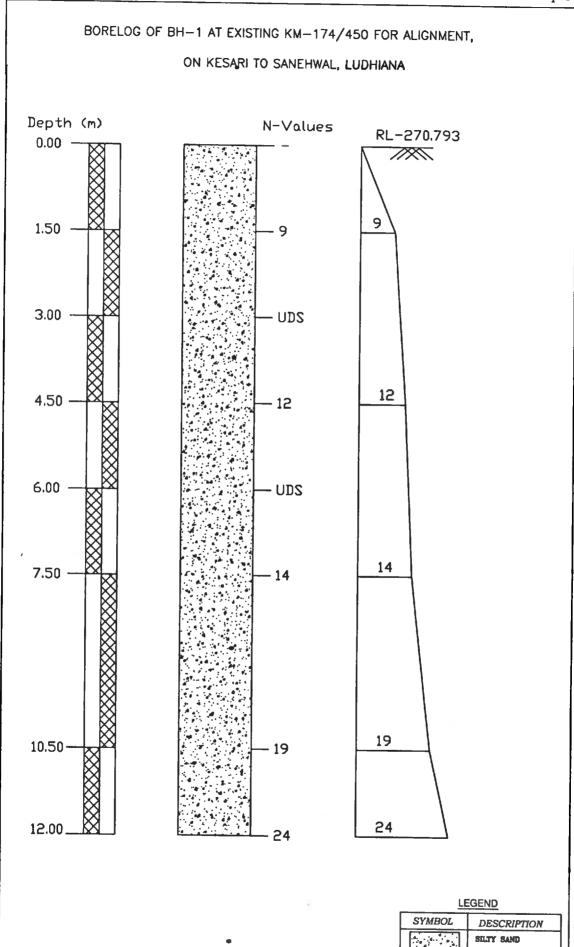
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				Date of Testino	_ 	Location at		T S	1	Death of Water Table	Table	1								
Project:	రే	Chainage 174/450	20	2000 Ct 0C -+ 000C Ct 0C			d		id in	or wate	L labie	194	lermination Depth	ulder			Surfac	Surface Elevation	c	
				29.12.2009 10 29.12.2009				_		08.00 m.			12.00mtr	Ť						
Depth	Observ-	Correction	Corrected	Soil		5	ain Size Di	Grain Size Distribution % wt retained	6 wt retain	2		Atter	Atterberg Limits %	ts %	B.D.	M.C.	D.D. S	Specific	Shear Strength	angth
mou	8	Factor		Description	Š	å		Sand		ð	Gravel						3	Gravity		•
GL (m)	z	ပ်	ź	(Soil Group)	3	ā	Fine	Medium	Coarse	Fine	Coarse	1	P.L	P.I.	да/сс	8	эт/сс	Ť	c kg/cm²	degree
0.00				Sity Sand	2.35	39.03	48.26	10.36	0.00	0.00	0.00	ន	불	₫.						
1.50	• 6	1.46	13.14	Sifty Sand	3.62	\$2.2	43.45	89	0.00	0.00	0.00	×S	Ę	• <u>₹</u>						
3.00	Sau			Silly Sand	0.00	9.36	54.74	38.30	0.00	0.00	0.00	ន	륄	<u>a</u>	1.70	13.62	1.50	2.68	0.00	29.5
4.50	12	1.09	13.08	Sily Sand	4.21	18.83	71.95	5.01	0.00	00.00	0.00	. 6	H H	2		,				,
8.00	san			Sity Sand	0.00	9.48	35.26	55.26	0.00	0.00	0.00	8	Ę	2	1.79	16.58	53.	2.66	0.00	29.0
7.50	14	0.91	12.74	Siky Sand	0.00	7.39	35.03	57.53	0.05	0.00	0.00	8	¥	2€		,	,			
10.50	19	0.80	15.10	Sily Sand	2.51	9.97	22.38	65.13	0.00	0.00	0.00	8	뒫	<u>Q</u>					,	
12.00	24	0.75	16.50	Silty Sand	0.00	5.06	20.46	74.49	0.00	0.00	0.00	82	불	<u>\$</u>				 .	.	
										1						1	1	979	C O N S U L T I N G Engineers Group Ltd.	Group La



ANNEXURE - III

Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 174 450	BH-1	
Type o	of footing			
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square	•	i i i i i i i i i i i i i i i i i i i	-
4	Circular	V.#3		
	of internal friction (o °)			29.50
	ion (c in t/m2)			0.00
Void ra				0.78
Direction	on of load with vertical (°)			0.00
Density	y of surcharge (t/m³)			1.70
Density	of foundation soil (t/m3)			1.70
	of water table(m)			•
	of safety			1.50
V 00101	Or Salety			3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,l_c+q\;(N_q\text{--}1)\;s_q\,d_q\;l_q+(1/2)\;B\;\gamma\;N_rs_rd_r^{\;i}_rW^*$

The ultimate net bearing capacity in case of local shear failure is given by $q_d' = (2/3) \ c \ N_c' \ s_c \ d_c' \ i_c + q \ (N_q' \ 1) \ s_q \ d_q \ i_q + (1/2) \ B \ \gamma \ N_v \ s_r \ d_r \ i_r \ W'$

Where

 $d_c = 1 + 0.2 (D_f/B)^*SQRT(N_\phi)$

 $d_q = d_y = 1$ for $\phi < 10^\circ$

 $d_q = d_{\gamma} = 1 + 0.1 (D/B)^*SQRT(N_0) \text{ for } \phi > 10^\circ$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

of for local shear failure = tan*1 (0.67 tane)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

ф	29.50	φ,	20.76
N _c	29.20	N' _c	15.73
N _q	17.63	N' _q	7.05
N _y _	21.25	N',	6.22

Shape factors:

S.no.	Width(m)	Length (m)		S.	Sq	S,
1	3.00	8.00	1	1.08	1.08	0.85
2	3.00	8.00	1	80.1	1.08	0.85
3	3.00	8.00	1	80.1	1.08	0.85
4	3.00	8.00	1	80.1	1.08	0.85
			•			

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d _q	d,
1	1.50	3.00	1.17	1.09	1.09
2	3.00	3.00	1.34	1.17	1.17
3	4.50	3.00	1.51	1.26	1.26
4	6.00	3.00	1.69	1.34	1.34

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1 - \alpha / 90)^{2}$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z_/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	24.83	8.44	8.44
2	3.00	3.00	8.00	44.59	15.58	15.58
3	4.50	3.00	8.00	47.85	16.72	16.72
4	6.00	3.00	8.00	51.11	17.86	17.86



Settlement Calculation As per IS 8009 (Part 1)			
Location	Alignment		
Chainage	174/450		
Bore Hole No.	1		

F (1 5 11 ()	
Footing Depth (m)	1.50
SBC (t/m2)	8.00
Average N value	13
Settlement for 10 t/m2 (mm)	26.00
Total Settlement (mm)	20.80
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	15.1

O

Footing Depth (m)	3.00
SBC (t/m2)	14.00
Average N value	12
Average in value	13
Settlement for 10 t/m2 (mm)	26.00
Total Settlement (mm)	36.40
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	24.2

	•
Footing Depth (m)	4.50
SBC (t/m2)	16.00
Average N value	13
Settlement for 10 t/m2 (mm)	26.00
Total Settlement (mm)	41.60
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	24.6

Footing Depth (m)	6.00
SBC (t/m2)	17.50
Average N value	14
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	38.50
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	20.9

CHAPTER - 23

"Alignment",

Location - Existing Km. - 177/02-03



23.1 LOCATION OF STRUCTURE:

Alignment at Existing Km. 177/02-03

23.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.50m below EGL

Subsurface profile at the site

BOREHOLE	•	Type of Soil/Rock	Soil/Rock
No.	(m)		Characteristics
	0.00 to 4.50	Sandy Silt with Clay	Loose
BH-1	4.50 to 6.00	Sandy Silt with Clay	Medium Dense
[6.00 to 10.50	Clayey Silt with Sand	Medium Dense
	10.50 to 12.00	Sandy Silt with Clay	Medium Dense

23.3 CHEMICAL ANALYSIS OF SOIL:

BORI	HOLE		CI	HEMICAL I	PROPERTI	ES	
No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity
	(m)			%	0/0	%	%
BH-1	3.00	7.70	NIL	0.0021	NIL	0.0012	0.044
D11-1	6.00	7.90	NIL	0.0022	NIL	0.0012	0.062

23.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	13.00
D11-1	6.00	18.00

23.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties		Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test	6.8	138	109	168	689	0.1	2.1	860	1352
Result]
Requirement	Not	2000 for	400	200	3000	5 ml of	25 ml of	-	-
as per IS: 456	less	CC and				0.02	0.02		!
/ Mosrth's	then	500 for				normal	normal		1
	6.0	RCC	•			NaoH	H ₂ SO ₄		

23.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	08.50
BH-1	3.00	12.00
	4.50	13.00
	6.00	14.00

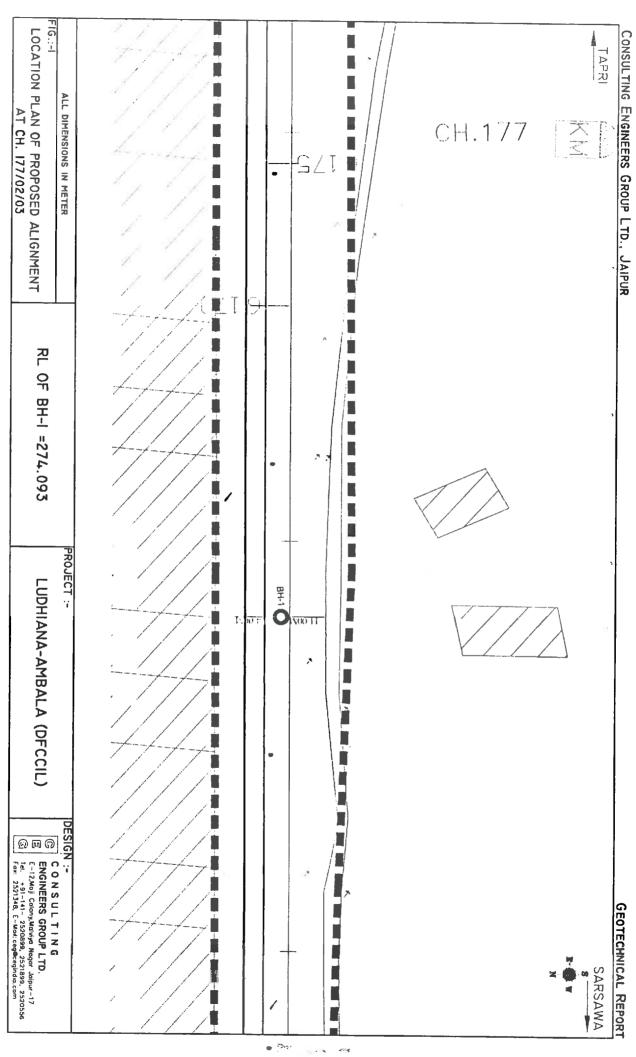
23.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

23.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



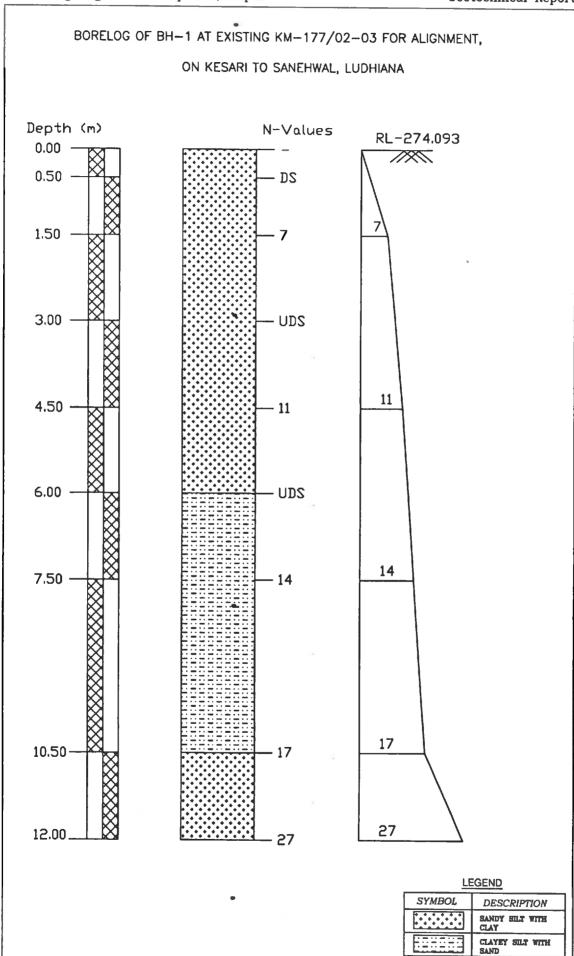
ANNEXURE - I

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6	sting	Locatio	ii c	9.H.	No.	Depth	of Water	Table	Termi	uation De	, tha		"	urlace Ele	vation	
ส	1,12,2009	1					07.50 ш.		-	2.00mtr						
_			Grai	n Size Dist	17 noinnain	wt retaine			Atterb	ing Limits	-				-	Shear Strength
få.	50	ì	ē		Sand		G	vel						Gravi	1	•
او	(dr	(g)	5	Fine	Medium	Coarse	Fine	Coarse	4	P.L.	P.I. gn			20/1	5	degree
5	th Clay	14,26	9073	15.62	6.35	1,15	0.56	000	æ	8	5			•	,	•
- 15	in Clay	12.36	64.70	16.36	5.24	99'0	99.0	00:00	8	24	01				•	
اصدا	th Clay	16.23	65.65	13.56	4.03	0.27	0.26	0.00	8	ន	5				·	'
ا سا	h Clay	11.96	56.49	24.34	4.32	1,60	1.30	0.00	8	ន	01				6, 0.12	19.0
_ '	h Clay	9.26	45.17	42.69	2.77	0.11	0.00	00.00	27	19	60			'	,	'
, - '	sand	96.90	70.86	10.27	2	0.19	0.50	0.00	38	*					0.15	17.0
- 12		14.86	17.77	90.9	1.31	0.04	0.00	0.00	39	27			· ,	•	•	,
1			67.76	20.25	1.52	0.25	0.10	000	8	ĸ	60					
<u> 44</u>	n Clay	8.95	69.79	20.02	1.19	000	0.00	000	N	19			<u>'</u>	•		,
,															S S S S S S S S S S S S S S S S S S S	COMSULTING Engineers Group Lid.
	Sandy Silt with Clayey Silt with Sandy Silt wi	Testing 5 28.12.2009 54 in piblon iroup) with Clay with Clay with sand with sand with Clay	14.26 14.26 14.26 14.26 14.26 10.12 10.12 8.96	14.26 62.0 14.26 62.0 16.23 65.4 11.95 66.4 14.86 77.77 10.12 67.76	Clay Sill 11.96 62.0 14.26 62.0 14.26 62.0 14.26 62.0 11.96 66.4 11.96 66.4 11.96 66.4 10.12 67.77 14.86 77.77 10.12 67.77	14.26 62.0 14.26 62.0 11.36 64.7 11.85 66.4 11.86 77.77 10.12 67.76	1	1 1 1 1 1 1 1 1 1 1	Clay Silt Fine Medium Coarse Fine 1.35 65.64 15.62 1.35 1.35 0.56 1.30 1	Clay Silt Fine Medium Coarse Fine Coarse Clay Silt Silt	Clay Silt Fine Medium Coarse Fine Coarse Clay Silt Silt	1	Location at B.H. No. Depth of Water Table Termination Depth 12.00mrf	Location at B.H. No. Depth of Water Table Termination Depth Termination Dept	Location at B.H. No. Depth of Water Table Termination Depth Termination Dept	Location at B.H. No. Depth of Water Table Termination Depth Surface Elevan Surface Elevan Surface Elevan Surface Surface Elevan Surface Surface



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

Type	of footing	

ре с	of footing	Ch 177 2-3	BH-1	
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			-
4	Circular			

Angle of internal friction (¢ °)	17.00
Cohesion (c in t/m2)	1.50
Void ratio (e)	0.68
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m3)	1.90
Depth of water table(m)	′ 1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d = c N_c s_c d_c i_c + q (N_q-1) s_q d_q i_q + (1/2) B \gamma N_\gamma s_\gamma d_\gamma i_\gamma W^*$

The ultimate net bearing capacity in case of local shear failure is given by $q_s' = (2/3) c N_c' s_c d_c i_c + q (N_q'-1) s_q d_q i_q + (1/2) B \gamma N_r' s_r d_r i_r W'$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_o)$

 $d_q = d_r = 1 \text{ for } \phi < 10^\circ$

 $d_q = d_\gamma = 1 + 0.1 (D/B)^*SQRT(N_0) \text{ for } \phi > 10^{\circ}$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

of for local shear failure = tan-1 (0.67 tano)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

¢	17.00	φ'	11.58
N _c	12.52	N' _e	9.18
N _q	4.92	N' _q	2.93
N _y	3.75	N' _y	1.67

Shape factors :

2 3.00 8.00 1.08 1.08	1.08 1.08 0.85
7.00	
3 3.00 8.00 1.08 1.08 0	4.65
	1.08 1.08 0.85
4 3.00 8.00 1.08 1.08 0	1.08 1.08 0.85

Depth factors:

S.no.	Depth(m)	Width(m)	dc	da	d,
1	1.50	3.00	1.14	1.07	1.07
2	3.00	3.00	1.27	1.14	1.14
3	4.50	3.00	1.41	1.20	1.20
4	6.00	3.00	1.54	1.27	1.27

inclination factors ;

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1-\alpha/90)^2$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z./B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	13.08	6.34	8.70
2	3.00	3.00	8.00	18.41	8.95	12.26
3	4.50	3.00	8.00	19.90	9.68	13.26
4	6.00	3.00	8.00	21.40	10.41	14.26
			•			



Settlement Calculation As per IS 800	9 (Part 1)			Align	nent Ch.	177/2-3
BH No. (A1)						·
Depth of foundation		=	1.5	m		
Length of footing (L)		=	8.0	m		
Width of footing (B)		=	3.0			
Initial effective stress at mid of layer	Po	=	6.75	t/m ²		
Concentrated load P		=		t/m ²		
Incerase in pressure at mid of layer	ΔΡ	=	PxI			
		I _B =	0.21	•		
	ΔΡ		1.8	t/m ²		
Compression Index	Cc	=	0.12	t/ III		
Thickness of clay layer	Н	=	4.5	m		
Initial Void ratio	e _o	=				
•	Po + Δp		1.26444	ŀ		
Settlement of clay layer	$S_{\mathbf{f}}$	=	Cc 1+ eo	- н	log 10	$\frac{Po + \Delta P}{Po}$
						10
	S _f	=	0.03275	i m		
		=	32.7535	mm		
Correction for Depth and Rigidity of for Depth Factor Calculation		=	32.7535	mm		
Correction for Depth and Rigidity of for Depth Factor Calculation	oundation	= on to	32.7535 tal settle	mm		
Depth Factor Calculation		= on to	32.7535 tal settle	mm		
Depth Factor Calculation	oundation D/(LB)^	= on to ,0.5 =	32.7535 tal settle 0.31	mm		
Depth Factor Calculation	oundation	= on to ,0.5 =	32.7535 tal settle	mm		
Depth Factor Calculation	oundation D/(LB)^	= on to ,0.5 =	32.7535 tal settle 0.31	mm		
Depth Factor Calculation D = Depth of Foundation	oundation D/(LB)^	= on tol ,0.5 _	32.7535 tal settle 0.31 2.67	mm		
Depth Factor Calculation D = Depth of Foundation Depth Factor	Oundation D/(LB)^ L/B	= on to 0.05 = =	32.7535 tal settle 0.31 2.67 0.91	i mm ment		
Depth Factor Calculation D = Depth of Foundation Depth Factor Tota	D/(LB)^L/B	= on tol	32.7535 tal settle 0.31 2.67 0.91 Rigid for	i mm ment		
Depth Factor Calculation D = Depth of Foundation Depth Factor	D/(LB)^L/B	= on tol	32.7535 tal settle 0.31 2.67 0.91 Rigid for	i mm ment	ndation	
Depth Factor Calculation D = Depth of Foundation Depth Factor Tota	D/(LB)^L/B	= on tol	32.7535 tal settle 0.31 2.67 0.91 Rigid for	i mm ment	ndation	
Depth Factor Calculation D = Depth of Foundation Depth Factor Tota	D/(LB)^L/B	= on tol	32.7535 tal settle 0.31 2.67 0.91 Rigid for	i mm ment	ndation	
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Total Total Settlen	D/(LB)^L/B	= on tol	32.7535 tal settle 0.31 2.67 0.91 Rigid for	i mm ment	ndation	
Rigidity Factor = Total Settler	D/(LB)^L/B	= on too	32.7535 tal settle 0.31 2.67 0.91 Rigid for	ment ment undation kible four	ndation	

O

Settlement Calculation As per IS 800	9 (Part 1)			Aligni	ment Ch. 1	177/2-3
BH No. (A1)						
Depth of foundation		=	3.0	m		
Length of footing (L)		=	8.0	m		
Width of footing (B)		=	3.0	m		
Initial effective stress at mid of layer	Po	=	9.45	t/m²		
Concentrated load P		=	12.00	t/m²		
Incerase in pressure at mid of layer	$\Delta \mathbf{P}$	=	PxIB			
		1 _B =	0.21			
	ΔΡ	· =	2.5	t/m ²		
Compression Index	Cc	==	0.12	,		
Thickness of clay layer	Н	$\tilde{a} = 0$	4.5	m		
Initial Void ratio	e _o	=	0.68			
	$\frac{\text{Po} + \Delta p}{\text{Po}}$		1.26667	•		
Settlement of clay layer	S_{f}	=	Cc 1+ eo	- н	log 10	$\frac{Po + \Delta P}{Po}$
	$S_{\mathbf{f}}$	=	0.033	m		
		=	32.9986	mm		
Correction for Depth and Rigidity of for Depth Factor Calculation	oundatior	on tol	al settle	ment		
	D/(LB)	^0.5 =	0.61			
	טן (נט)		0.02			
D = Depth of Foundation						
	L/B	=	2.67			
Depth Factor		=	0.83			
Tota	l Settleme	nt of F	Rigid for	ındation		
Rigidity Factor = Total Settler	nent at th	e centr	e of Fle	cible fou	indation	-
= 0.8						
Pore Pr. Correction= N.A.						
Total Settlement		=	S _f x D.I	F.x R.F.		
	S _{r2}	=	21.9	mm		



_	per IS 8009 (Pa	urt 1)		Alignm	ent Ch. 177/2-3
BH No. (A1)					
Depth of foundation		=	4.5	m	
Length of footing (L)		=	8.0	m	
Width of footing (B)		=	3.0	m	
Initial effective stress at mid	of lay Po	=	12.69	t/m ²	
Concentrated load P		=	13.00	t/m²	
Incerase in pressure at mid o	of lay€∆P	=	PxIB	-,	
	•	1 _B =	0.21		
	ΔΡ	=	2.7	t/m²	
Compression Index	Cc	=	0.12	-/	
Thickness of clay layer	Н	=	4.5	m	
Initial Void ratio	e _o	=	0.68		
	<u>Po + Δp</u> <u>Po</u>		1.21513		
Settlement of clay layer	S_{f}	=	Cc 1+ eo	- н	$\log_{10} \frac{Po + \Delta}{Po}$
	S_{f}	=	0.0272002	m	
		=	27 20017	F2 52	
Correction for Depth and Rig	gidity of found	= lation on	27.20017 total settler	mm nent	
Correction for Depth and Rig Depth Factor Calculation	gidity of found	= lation on	27.20017 total settler	mm nent	
Correction for Depth and Rig Depth Factor Calculation			total settlen	mm nent	
Depth Factor Calculation	gidity of found		27.20017 total settler 0.92	mm nent	
Correction for Depth and Rig Depth Factor Calculation D = Depth of Foundation			total settlen	mm nent	
Depth Factor Calculation		0.5 =	total settlen	mm nent	
Depth Factor Calculation	D/(LB)^	0.5 =	total settlen	mm nent	
Depth Factor Calculation D = Depth of Foundation	D/(LB)^		0.92 2.67	mm nent	
Depth Factor Calculation	D/(LB)^	0.5 =	total settlen	mm nent	
Depth Factor Calculation D = Depth of Foundation Depth Factor	D/(LB)^ L/B Total Sett	0.5 = = = = = = = = = = = = = = = = = = =	0.92 2.67 0.74 of Rigid four	nent	
Depth Factor Calculation D = Depth of Foundation Depth Factor	D/(LB)^ L/B	0.5 = = = = = = = = = = = = = = = = = = =	0.92 2.67 0.74 of Rigid four	nent	lation
Depth Factor Calculation D = Depth of Foundation Depth Factor	D/(LB)^ L/B Total Sett	0.5 = = = = = = = = = = = = = = = = = = =	0.92 2.67 0.74 of Rigid four	nent	lation
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Total	D/(LB)^ L/B Total Sett	0.5 = = = = = = = = = = = = = = = = = = =	0.92 2.67 0.74 of Rigid four	nent	lation
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Tot = 0.8	D/(LB)^ L/B Total Sett	0.5 = = = = = = = = = = = = = = = = = = =	0.92 2.67 0.74 of Rigid four	nent	lation —
Depth Factor Calculation Depth Factor Depth Factor Rigidity Factor = Tot = 0.8 Pore Pr. Correction= N.A.	D/(LB)^ L/B Total Sett	0.5 = = = = = = = = = = = = = = = = = = =	0.92 2.67 0.74 of Rigid four	ndation ble found	lation
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Tot = 0.8	D/(LB)^ L/B Total Sett	0.5 = = = = = = = = = = = = = = = = = = =	0.92 2.67 0.74 of Rigid four	ndation ble found	lation



Settlement Calculation As p	er IS 8009 (Pa	rt 1)		Alignm	ent Ch. 1	77/2-3
BH No. (A1)						
Depth of foundation		=:	6.0	m		
Length of footing (L)		=	8.0	m		
Width of footing (B)		=	3.0	m		
Initial effective stress at mid	of lay Po	=:	15.51	t/m ²		
Concentrated load P		=	14.00	t/m ²		
Incerase in pressure at mid or	f lay€∆P	=	PxlB	•		
	_	1 _B =	0.21			
	ΔΡ	=	2.9	t/m²		
Compression Index	Cc Cc	=	0.12	-,		
Thickness of clay layer	Н	=	4.5	m		
Initial Void ratio	e _o	=	0.68			
	$\frac{Po + \Delta p}{Po}$	_ =	1.1895551	l		
Settlement of clay layer	S_f	=	Cc 1+ eo	- н	log 10	Po + ΔP
			2			
	c	2				
	S _f	=	0.0242308	3 m		
Correction for Depth and Rig Depth Factor Calculation		= = lation on	0.0242308 24.230756	3 m 5 mm		
			0.0242308 24.230756	3 m 5 mm		
	idity of found		0.0242308 24.230756 total settler	3 m 5 mm		
Depth Factor Calculation	idity of found	/D =	0.0242308 24.230756 total settler	3 m 5 mm		
Depth Factor Calculation	gidity of found	/D =	0.0242308 24.230756 total settler 0.82	3 m 5 mm		
Depth Factor Calculation D = Depth of Foundation	gidity of found (LB)^ ^{0.5} / L/B	'D = =	0.0242308 24.230756 total settler 0.82 2.67	3 m 5 mm ment		
Depth Factor Calculation D = Depth of Foundation Depth Factor	gidity of found (LB)^ ^{0.5} / L/B	'D = =	0.0242308 24.230756 total settles 0.82 2.67 0.68 of Rigid fou	3 m 6 mm ment	ndation	-
Depth Factor Calculation D = Depth of Foundation Depth Factor	(LB)^0.5/ L/B	'D = =	0.0242308 24.230756 total settles 0.82 2.67 0.68	3 m 6 mm ment	ndation	-
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = To	(LB)^0.5/ L/B	'D = =	0.0242308 24.230756 total settles 0.82 2.67 0.68	3 m 6 mm ment	ndation	
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = To	(LB)^0.5/ L/B	'D = =	0.0242308 24.230756 total settles 0.82 2.67 0.68	3 m 5 mm ment undation kible foun	dation	-



CHAPTER - 22

"Alignment",

Location - Existing Km. - 180/15-17



22.1 LOCATION OF STRUCTURE:

Alignment at Existing Km. 180/15-17

22.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.00m below EGL

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
	0.00 to 1.50	Silty Sand with Gravels	Loose
BH-1	1.50 to 3.00	Silty Sand with Gravels	Medium Dense
	3.00 to 12.00	Silty Sand	Medium Dense

22.3 CHEMICAL ANALYSIS OF SOIL:

BOR	EHOLE	CHEMICAL PROPERTIES					
No.	Depth (m)	pН	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	7.90	NIL	0.0022	NIL	0.0011	0.062
	6.00	8.10	NIL	0.0021	NIL	0.0011	0.072

22.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No. •	Depth (m)	DFS Index in %
BH-1	3.00	NIL
2111	6.00	NIL

22.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties		Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	7.3	136	96	150	746	0.3	3.3	901	1397
Requirement as per 15:456 / Mosrth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	-	-

22.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	10.00
BH-1	3.00	19.00
D11-1	4.50	20.00
	6.00	21.50

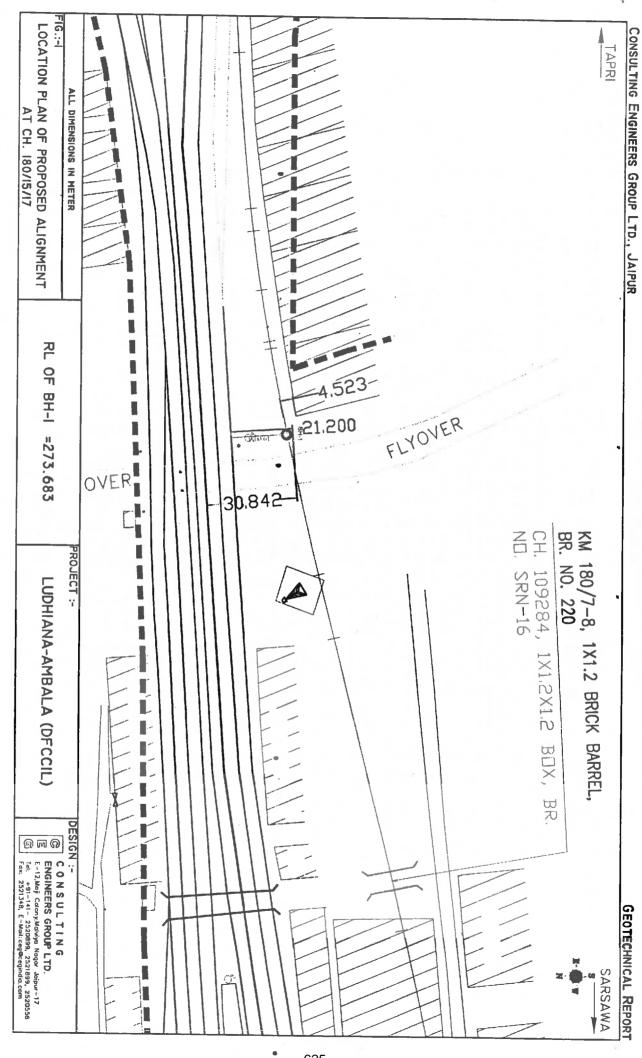
22.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

22.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 3.00 m from EGL

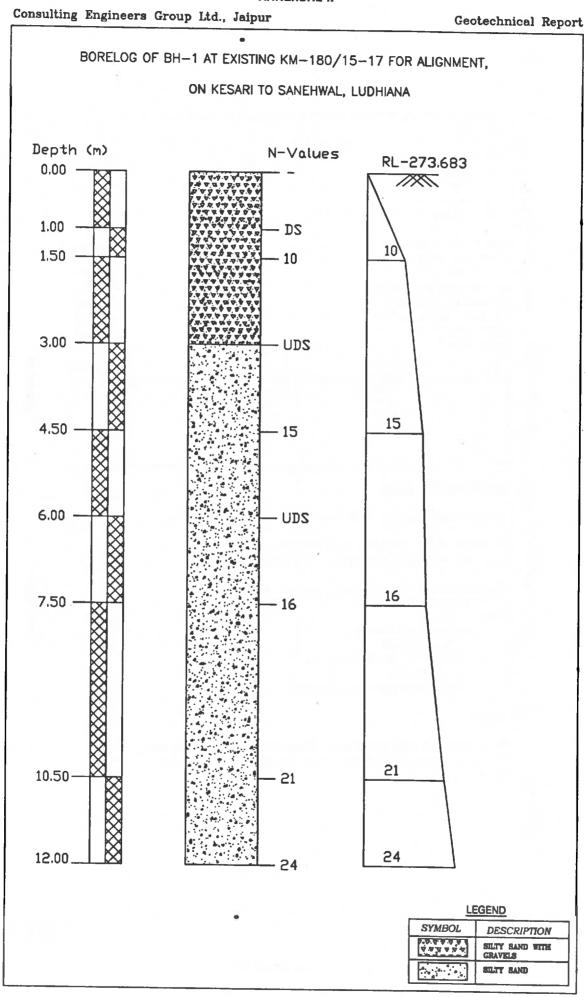
Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

																				1
Project :		Chainage 180/17-19	-19	Date of Testing	to	Location at	66	B.H. No.	Dept	Depth of Water Table	Table	Tem	Termination Depth	thde			Surfac	Surface Elevation	8	
.				26.12.2009 to 26.12.2009		-		1		07.00 m.			12.00mtr							
Depth	Observ-	Correction	Corrected	Sol		Ď	ain Size D	Grain Size Distribution % wt retained	6 wt retain	2		Affert	Afterberg Limits %	% s1	B.D.	M.C.	D.D.	Specific	Shear Strength	ength
from	8	Factor		Description	ě	â		Sand		Ö	Gravel					-		Gravity		•
GL (m)	z	ర్	Z,	(Soil Group)	3	7	Fine	Medium	Coarse	Fine	Coarse	1	P.L.	1.	аш/сс	96	gm/cc		c kg/cm²	degree
0.00				Silty Sand with Gravels	2,65	11.54	32.38	46.15	6970	6.59	0.00	ន	皇	₽ D						
1.00	SO			Sity Sand with Gravels	3.21	4.92	35 24	48 .62	12	5.49	00:00	24	Z Z	ů. Ž						
1.50	10	1.44	14,40	Sity Sand with Gravels	8.0	6.75	38.19	46.82	0.39	7.85	0.00	ĸ	륃	<u>a</u>	 .		 .			
3.00	Sau			Silty Sand	8.0	8.78	38.06	52.02	41.0	0.00	0.00	য়	킬	<u>a</u>	28.	14.36	1.59	2.69	0.00	27.0
4.50	15	1.07	16.05	Silty Sand	0.00	8.66	22.60	67.28	0.42	9.	0.00	27	불	<u>a</u>			<u> </u>		1	
6.00	san			Silty Sand	88 88	19.92	12.36	62.37	0.35	8.	0.00	88	불	d Z	58.	16.39	1.65	2.65	90.00	28.0
7.50	16	0.89	14.24	Silty Sand	4.66	23.75	28.	60.54	0.52	1,71	000	8	불	<u>2</u>	,		 			
10.50	21	0.77	15.59	Silty Sand	83	8.41	38.18	47.39	0.46	1.30	0.00	8	뒫	<u>a</u>	 .		-	<u> </u>		
12.00	24	0.73	16.26	Sify Sand	4.86	5.21	26.57	58.74	0.43	4.39	0.00	श	a Z	<u>a</u>	 	 				
													1	1		1	-	980	CONSULTING Engineers Group Library	Group Lie
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Calculation of SBC for shallow foundations as per IS: 6403 - 1981

		Cn 180 15-17	BH-1	ļ
Туре о	f footing			
1	Continuous Strip		Γ	
2	Rectangular		Rectangular	2
3	Square			
4	Circular			
			_	

Angle of internal friction (o °)	27.00
Cohesion (c in 1/m2)	0.00
Void ratio (e)	0.69
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (Vm³)	1.82
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)		Width (m)	Length (m)
1	1.50		3.00	8.00
2	3.00		3.00	8.00
3	4.50	•	3.00	8.00
4	6.00		3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,i_c+q\;(N_q-1)\;s_q\,d_q\,i_q+(1/2)\;B\;\gamma\,N_y\,s_y\,d_y\,i_y\,W'$

The ultimate net bearing capacity in case of local shear failure is given by

 $q'_d = (2/3) c N'_c s_c d_c i_c + q (N'_q-1) s_q d_q i_q + (1/2) B \gamma N'_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_0)$

 $d_q = d_\gamma = 1$ for $\phi < 10^\circ$

 $d_q = d_y = 1 + 0.1 (D_y/B)^*SQRT(N_\phi) \text{ for } \phi > 10^\circ$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

ø' for local shear failure = tan-1 (0.67 tanø)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.



Bearing capacity factors :

ф	27.00
N _c	24.49
N _q	13.76
L N ₇	15.49

φ.	18.85
N'c	13.94
N' _q	5.83
N' _y	4.76

Shape factors:

S.no.	Width(m)	Length (m)	Sc	Sa	S.
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	
4	3.00	8.00			0.85
		0.00	1.08	1.08	0.85

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d _o	d.
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.24	1.24
4	6.00	3.00	1.65	1.33	1.33

Inclination factors:

$i_c = (1-\alpha/90)^2$	$\hat{i}_0 = (1 - \alpha / 90)^2$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z_/B	W.
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	
4	6.00	3.00	-1.50	0.50
		0.00	-1.30	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	19.09	6.77	10.46
2	3.00	3.00	8.00	34.08	12.42	18.92
3	4.50	3.00	ი.00	36.47	13,29	20.24
4	6.00	3.00	8.00	38.86	14.16	21.57

Settlement Calculation As per IS 8009 (Part 1)							
Location	Alignment						
Chainage 180/15-17							
Bore Hole No.	1	00					

Footing Depth (m)	1.50
SBC (t/m2)	10.00
Average N value	15
Settlement for 10 t/m2 (mm)	22,00
Toatl Settlement (mm)	22.00
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	16.0

Footing Depth (m)	3.00
SBC (t/m2)	19.00
Average N value	16
Settlement for 10 t/m2 (mm)	19.00
Toatl Settlement (mm)	36.10
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	24.0

Ö

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Footing Depth (m)	4.50
SBC (t/m2)	20.00
Average N value	16
-	
Settlement for 10 t/m2 (mm)	20.00
Toatl Settlement (mm)	40.00
	•
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	23.7

Footing Depth (m)	6.00
SBC (t/m2)	21.50
Average N value	16
Average IV value	10
Settlement for 10 t/m2 (mm)	20.00
Toatl Settlement (mm)	43.00
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	23.4

CHAPTER - 21

"Alignment",

Location - Existing Km. - 181/15-17



21.1 LOCATION OF STRUCTURE:

Alignment at Existing Km. 181/15-17

21.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.00m below EGL

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
	0.00 to 3.00	Silty Sand with Gravels	Loose
BH-1	3.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

21.3 CHEMICAL ANALYSIS OF SOIL:

BORI	EHOLE	CHEMICAL PROPERTIES					
No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity
	(m)			%	0/0	%	%
BH-1	3.00	8.60	NIL	0.0028	NIL	0.0013	0.088
DI 1-1	6.00	8.40	NIL	0.0021	NIL	0.0013	0.062

21.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
D11-1	6.00	NIL

21.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit		Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	7.1	132	105	163	853	0.3	1.2	1036	1562
Requirement as per 15:456 / Mosrth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	-	-

21.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	09.00
BH-1	3.00	16.00
D11-1	4.50	20.00
	6.00	21.50

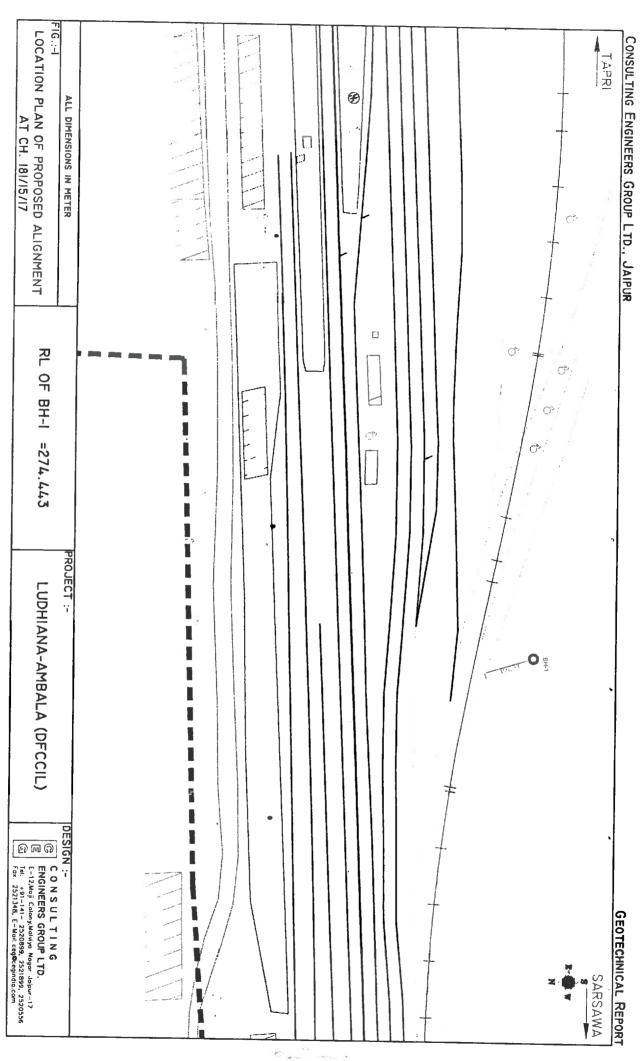
21.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

21.8 RECOMMENDATIONS

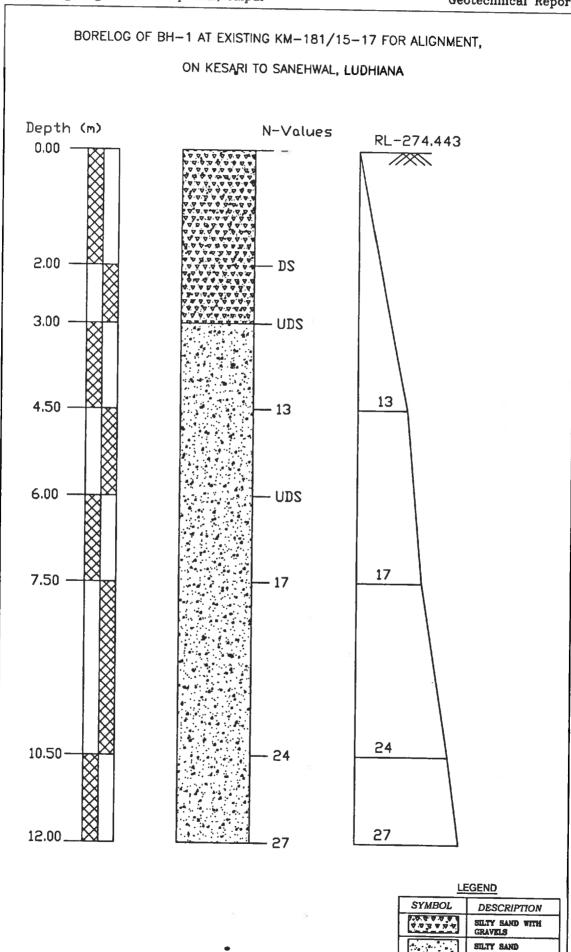
(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 3.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

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Brained -		Chainean 18117.10	7.40	Date of Testing	Log	Location at	8	B.H. No.	Depti	Depth of Water Table	r Table	Tem	Termination Depth)epth			Surfa	Surface Elevation	ion	
. roject .	5	/1/101 afterna	n .	25.12.2009 to 25.12.2009	_	_		_		07.00 m.			12.00mtr							
Depth	Observ-	Correction	Corrected	Soil		Š	Grain Size Di	Distribution % wt retained	6 wt retain	D.		Atte	Atterberg Limits	its %	B.D.	M.C.	D.D.	Specific	Shear Strength	ength
E Qu	8	Factor		Description	į	å		Sand		Ō	Gravel							Gravity	·	•
GL (m)	z	౮	ž	(Soil Group)	2	ā	Fine	Medium	Coarse	Fine	Coarse	LL	P.L	P.I.	gm/cc	36	gm/cc		c kg/cm²	eausep
0.00		• .	•	Sifty Sand with Gravels	0.00	8.03	32.15	50.65	1.25	7.56	0.36	%	Ę	<u>₹</u>						'
2.00	• O			Sifty Sand with Graveis	0.00	10.11	30.26	52.45	1.12	29.tz	0.42	10	불	• ª					,	
3.00	san			Silty Sand	2.65	13.25	30.33	49.66	0.90	3.21	0.00	22	불	Š	1.82	14.63	1.58	2.68	00:00	27.0
4.50	13	1.07	13.91	Salty Sand	0.00	8.05	40.85	49.81	0.39	0.90	0.00	88	불	ě				,		
6.00	SON		,	Sifty Sand	0.00	9.97	62.62	25.64	0.65	27.7	0.00	8	Ę	2	1.89	15.63	59.1	2.67	0.00	29.0
7.50	17	0.89	15.07	Silty Sand	0.00	7.53	68.45	20.80	0.42	2.80	0.00	R	불	§.						,
10.50	24	0.78	16.86	Sity Sand	2.26	9.57	39.11	48.06	0.66	26.0	0.00	R	Ę	2	,		,			
12.00	27	0.73	17.36	Silty Sand	0.00	5,65	70.20	20.77	0.25	3.13	0.00	8	불	<u>a</u>						
																		OPC.	Engineers Group Ltd.	Group L



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 181 15-17	BH-1	
Type	of footing			
1	Continuous Strip			
2	Rectangular	•	Rectangular	2
3	Square			· ·
4	Circular			
Angle	of internal friction (\$ °)			27.00
	ion (c in t/m2)			0.00
Void ra	atio (e)			0.69
Directi	on of load with vertical (°)			0.00
	y of surcharge (t/m³)			1.70
Densit	y of foundation soil (t/m3)			1.82
	of water table(m)			1.50
	of safety			3.00

S.no.	Depth (m)	Width (m)	Length (m)
1 -	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,l_c+q\;(N_q\text{--}1)\;s_q\,d_q\,l_q+(1/2)\;B\;\gamma\,N_\gamma s_\gamma\,d_\gamma l_\gamma W^*$

The ultimate net bearing capacity in case of local shear failure is given by $q'_d = (2/3) \ c \ N'_c \ s_c \ d_c \ l_c + q \ (N'_q-1) \ s_q \ d_q \ l_q + (1/2) \ B \ \gamma \ N'_\gamma \ s_\gamma \ d_r \ l_\gamma \ W'$

Where,

 $d_c = 1 + 0.2 (D_r/B)^* SQRT(N_\phi)$ $d_q = d_r = 1 \text{ for } \phi < 10^\circ$

 $d_q = d_y = 1 + 0.1 (D_y/B)^*SQRT(N_\phi) \text{ for } \phi > 10^\circ$

 $N_0 = \tan^2(\pi/4 + \phi/2)$

φ' for local shear failure = tan-1 (0.67 tanφ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

ø	27.00
N _c	24.49
N _q	13.76
N _y	15.49

φ'	18.85
N' _c	13.94
N' _q	5.83
N' _y	4.76

Shape factors:

S.no.	Width(m)	Length (m)		S _c	S _q	S,
1	3.00	8.00		1.08	1.08	0.85
2	3.00	8.00	•	1.08	1.08	0.85
3	3.00	8.00		1.08	1.08	0.85
4	3.00	8.00		1.08	1.08	0.85
i						

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d _q	d,
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.24	1.24
4	6.00	3.00	1.65	1.33	1.33

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1 - \alpha / 90)^{2}$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z"/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	19.09	6.77	10.46
2	3.00	3.00	8.00	34.08	12.42	18.92
3	4.50	3.00	8.00	36.47	13.29	20.24
4	6.00	3.00	8.00	38.86	14.16	21.57



Sett	lement Calculation As per IS 8009 (Par	t 1)
Location	Alignment	
Chainage	181/15-17	
Bore Hole No.	1	

1.50
9.00
10
36.00
32.40
0.91
0.8
23.6

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	14
Settlement for 10 t/m2 (mm)	23.00
Total Settlement (mm)	36.80
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	24.4

Footing Depth (m)	4.50
SBC (t/m2)	20.00
Average N value	15
Settlement for 10 l/m2 (mm)	21.00
Total Settlement (mm)	42.00
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	24.9

Footing Depth (m)	6.00
SBC (t/m2)	21.50
Average N value	15
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	45.15
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	24.6

CHAPTER - 20

"Alignment",

Location - Existing Km. - 186/00-01



20.1 LOCATION OF STRUCTURE:

Alignment at Existing Km. 186/00-01

20.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 6.00m below EGL

Subsurface profile at the site

BOREHOLE	Depth	Type of Soil/Rock	Soil/Rock	
No.	(m)	•	Characteristics	
	0.00 to 3.00	Clayey Silt with Sand	Loose	
[3.00 to 4.50	Sandy Silt with Clay	Loose	
BH-1	4.50 to 6.00 •	Sandy Silt with Clay	Medium Dense	
[6.00 to 7.50	Silty Sand with Clay	Medium Dense	
	7.50 to 12.00	Sandy Silt with Clay	Medium Dense	

20.3 CHEMICAL ANALYSIS OF SOIL:

BORE	HOLE	CHEMICAL PROPERTIES					
No.	Depth	pH Carbonate		Chlorides	Sulphate	Nitrate	Salinity
	(m)			%	°/o	%	%
BH-1	3.00	8.10	NIL	0.0021	NIL	0.0012	0.049
D11-1	6.00	8.30	NIL	0.0020	NIL	0.0012	0.052

20.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	14.00
D11-1	6.00	14.00

20.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

					DITED IV	ANA DICE.	KOM BOL	CL HOLI	4
			Sulphate	Organic	Inorganic	Acidity	Alkalinity	Total	Conducti
Chemical	Value	mg/lit	mg/lit	Matter	Matter	(ml)	(ml)	Disso.	vity
Properties				mg/lit	mg/lit			Solids	(µS/cm)
								(ppm)	
Test	6.7	72	136	119	708	0.4	5.4	884	1392
Result						,			
Requirement	Not	2000 for	400	200	3000	5 ml of	25 ml of	-	-
as per IS:456	less	CC and				0.02	0.02		
/ Mosrth's	then	500 for				normal	normal		
	6.0	RCC				NaoH	H ₂ SO ₄		

20.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	08.00
BH-1	3.00	12.00
D11-1	• 4.50	13.00
	6.00	14.00

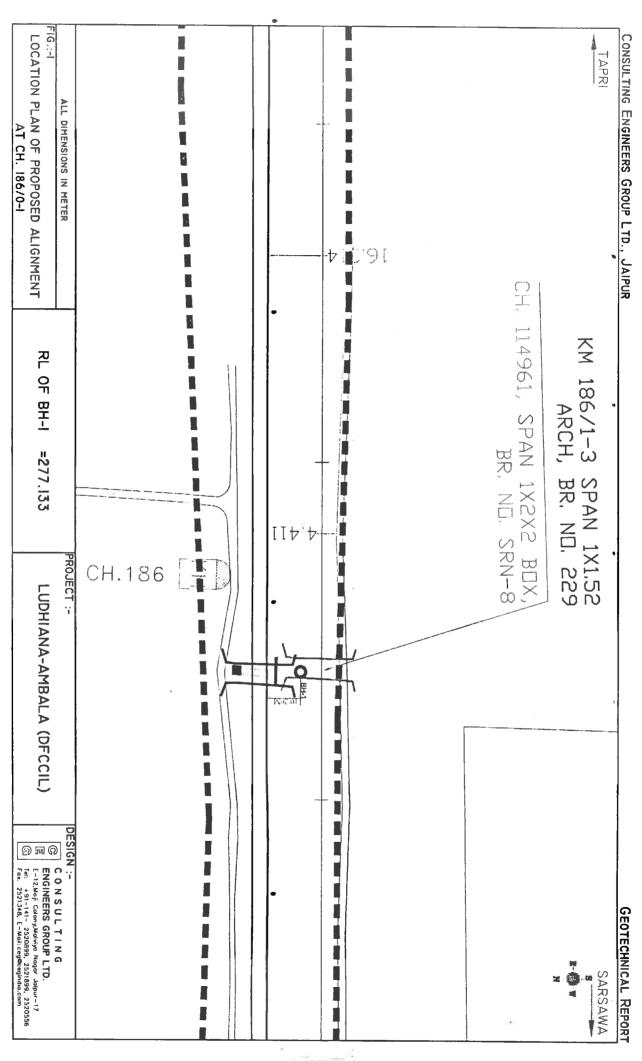
20.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

20.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



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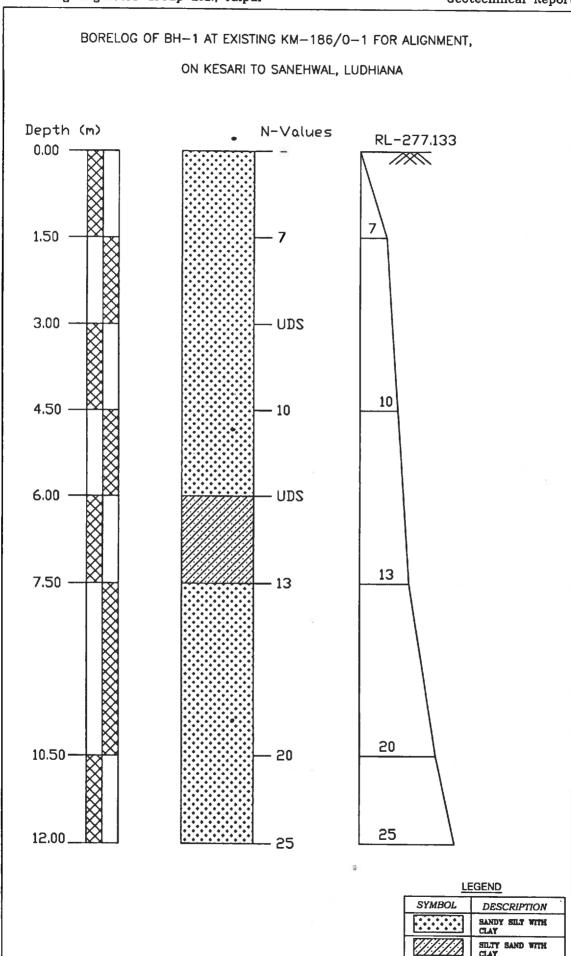
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Containing Section Act Containing Section Con					Date of Testing	Locat	ion at	H.8	l. No.	Depth	ol Water	Table	Termi	nation D	epth			Surfac	e Elevatio	E	
Cobant- Correction Solid Solid Colored- Solid Colored- Solid Colored-	Toject :	200	inage 186/01.	ğ	22.12.2009 to 22.12.2009				_		06.00 m			2.00mtr							
ed Factor N. Change plan Str Factor Change Str Andron Change Str Andron Change LL Fine Change Change LL Fine Change Change<	Depth	Obsen-	Correction		Soil		Gra	in Size Dis	stribution %	wt retaine	P		Attent	verg Limi	* 8	B.D.	M.C.			Shear Stre	ugth
N C., N. N. (Soli Geoup.) Cart Clayey Silk with Sand 12.36 74.06 6.56 1.45 0.267 0.51 0.507 0.51 0.507 0.51	from	8	Factor		Description	į	100		Sand		ug Gu	avel						9		7	•
1.14 10.08 Clayey Sile with Clay 11.24 10.08 Clayey Sile with Clay 11.24 10.08 Clayey Sile with Clay 11.24 10.08 12.75 1.44 10.08 12.75 1.44 11.24 12.75 1.46 1.45 1.25	GL (m)	Z	င်	ź	(Sail Group)	Ç g	á	Fine	Medium	Coarse	Fine	Coarse	4	P.L.		эш/ос		дш/сс			degree
1.00 1.00 1.00 Clayey Site with Clay 11.24 68.40 14.89 0.56 0.27 3.24 0.00 35 25 10 1.78 13.25 1.57 2.83 2.14 1.15 2.83 2.14 1.15 2.83 2.14 1.15 2.83 2.14 1.15 2.83 2.14 1.15 2.14 2.15 2.15	0.00	•		,	Clayey Silt with Sand	12.36	74.03	6.58	2.24	1,14	3.65	0.00	2	24	0			,	•		'
10 1.08 1.0.80 Sandy Sill with Clay 11.84 68.40 14.69 0.56 0.27 3.24 0.00 35 25 10 1.78 13.29 1.57 2.83 1.0 1.08 1.08 0.09 11.70 Sandy Sill with Clay 12.53 68.52 13.31 0.56 0.10 0.00 0.00 32 22 10 1.86 19.67 1.55 2.82 1.0 1.82 1.0 1.2	1.50	۲.	4.	10.08	Clayey Silt with Sand	12.76	75.41	5.06	1.43	0.83	4.51	0.00	37	92	=	•					•.
10 1.08 10.30 Sandy Sili with Clay 18.55 66.91 1.554 0.91 0.653 0.76 5.40 30 22 8	3.00	san			Sandy Sill with Clay	11.84	68.40	14.69	0.56	0.27	3.24	0.00	×	25	10	1.78	13.28	1.57	2.63	0.13	18.(
UDS Selty Sand with Clay 11.36 14.46 71.22 2.96 0.00 0.00 32 22 10 1.86 19.67 1.55 2.62 20 0.76 15.30 Sandy Silt with Clay 13.00 67.07 17.76 1.01 0.46 0.70 3.00 35 24 11	05.30	9	1.08	10.80	Sandy Silt with Clay	9.85	66.91	15.54	0.91	59'0	0.76	5.40	30	8	80					•	
13 0.90 11.70 Sandy Silt with Clay 12.53 68.52 13.31 0.56 0.10 4.96 0.00 34 23 11 - · · · · · · · · · 20 0.76 15.30 Sandy Silt with Clay 13.00 67.07 17.76 1.01 0.46 0.70 0.00 35 24 11 - · · · · · · · · · · · · · · · · ·	90.50	SON			Sity Sand with Clay	11.36	14.46	71.22	2.98	0.00	00:0	0.00	R	8	10	1.86	19.67	1.55	2.62	0.11	6
20 0.78 15.30 Sandy Silt with Clay 13.00 67.07 17.76 1.01 0.46 0.70 0.00 35 24 11	7.50	5	0.90	11.70	Sandy Silt with Clay	12.53	68.52	13.31	0.56	0.10	4.96	0.00	*	ន	=	,		,	,		•
25 0.74 16.75 Sandy Silt with Clay 14.36 61.07 20.36 2.14 1.12 0.95 0.00 36 24 12	0.50	50	0.78	15.30	Sandy Såt with Clay	13.00	20.79	17.76	1.01	0.46	0.70	0.00	SS	24	1	,	ı				'
Engineers Group Engineers Group Engineers Group Engineers Group	2,00	52	0.74	16.75	Sandy Silt with Clay	14.36	61.07	20.38	2.14	1.12	0.95	0.00	8	2	51		,				٠
																			OEU.	C O N S Engineers	Group



Calculation of SBC for shallow foundations as per IS: 6403 - 1981

INPUT DATA

		Cn 186/0-1	BH-1	
Туре с	of footing			
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			_
4	Circular			
Angle (of internal friction (¢°)	•		19.00
Cohesi	ion (c in t/m2)			1.10
	4-4-5			

4	4.50		
S.no.	Depth (m)	Width (m)	Length (m)
Factor of safety	у		3.0
Depth of water	• •		1.5
	ndation soil (t/m3)		1.1
Density of surc			1.
	nd with vertical (°)		0.0
void ratio (e)			0.0

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below-

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\ N_c\ s_c\ d_c\ l_c+q\ (N_q-1)\ s_q\ d_q\ i_q+(1/2)\ B\ \gamma\ N_y\ s_z\ d_y\ i_z\ W'$

The ultimate net bearing capacity in case of local shear failure is given by $q'_d = (2/3) c N'_c s_c d_c i_c + q (N'_q-1) s_q d_q i_q + (1/2) B \gamma N'_\gamma s_\gamma d_\gamma i_\gamma W'$

Where,

$$\begin{split} &d_{c}=1+0.2~(D/B)^{\circ}SQRT(N_{\phi})\\ &d_{q}=d_{\gamma}=1~for~\phi<10^{\circ}\\ &d_{q}=d_{\gamma}=1+0.1~(D/B)^{\circ}SQRT(N_{\phi})~for~\phi>10^{\circ}\\ &N_{\phi}=tan^{2}(\pi/4+\phi/2)\\ &\phi'~for~local~shear~failure=tan^{-1}~(~0.67~tan\phi~) \end{split}$$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

ф	19.00	φ,	12.99
N _c	14.06	N'c	9.92
Nq	5.91	N' _q	3.35
N ₇	4.84	N' _Y	2.08

Shape factors:

S.no.	Width(m)	Length (m)	S _c	S_q	S,
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	dq	d,
1	1.50	3.00	1.14	1.07	1.07
2	3.00	3.00	1.28	1.14	1.14
3	4.50	3.00	1.42	1.21	1.21
4	6.00	3.00	1.56	1.28	1.28

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_0 = (1 - \alpha / 90)^2$	$i_{\gamma} = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)		Z _w /B	W'
1	1.50	3.00		0.00	0.50
2	3.00	3.00	•	-0.50	0.50
3	4.50	3.00		-1.00	0.50
4	6.00	3.00		-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	13.17	6.15	8.25
2	3.00	3.00	8.00	19.50	9.17	12.27
3	4.50	3.00	8.00	21.04	9.89	13.24
4	6.00	3.00	8.00	22.58	10.62	14.21

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Settlement Calculation As per IS	3009 (Part 1)				Alig	nment C	h. 186/0-
BH No. (A1)							
Depth of foundation			=	1.5	m		
Length of footing (L)			=	8.0	m		
Width of footing (B)			=	3.0	m		
Initial effective stress at mid of laye	er e	Po	=	6.68	t/m ²		
Concentrated load P			=	8.00	t/m ²		
Incerase in pressure at mid of layer		ΔΡ	=	PxIB	·/ ···		
			1 _B =	0.21			
		ΔР	· B	1.7	t/m²		
Compression Index		Cc	=	0.12	t/ III		
Thickness of clay layer		н	=	4.5	m		
Initial Void ratio		e _o	=	0.69			
		Po + A					
Settlement of clay layer		S _f		Cc 1+ eo	- н	log 10	Po + A
		S _f	=	0.031	m		
Correction for Depth and Rigidity of Depth Factor Calculation	of foundation	on total s	= ettlement	31.15	mm		
		D/(LB)^0.5 =	0.31			
D = Depth of Foundation		٥, (٥٥	,				
		T /1	3 =	2.67			
		L/					
Depth Factor		L/	=	0.91			
Depth Factor			=		dation		
Depth Factor Rigidity Factor =		Total Sett	= lement o	0.91 of Rigid foun			
	Total Se	Total Sett	= lement o	f Rigid four			
Rigidity Factor =	Total Se	Total Sett	= lement o	f Rigid four			
Rigidity Factor = Pore Pr. Correction=	Total Se	Total Sett	= lement o	of Rigid four ntre of Flexi	ble four		
	Total Se	Total Sett	element of at the cer	f Rigid four	ble four		

(7)

O



Settlement Calculation As per IS 8009	(Part 1)				Alignm	ent Ch.	186/0-1
BH No. (A1)							
Depth of foundation			=	3.0	m		
Length of footing (L)			=	8.0	m		
Width of footing (B)			=	3.0	m		
Initial effective stress at mid of layer		Po	=	9.35	t/m²		
Concentrated load P			=	12.00	t/m²		
Incerase in pressure at mid of layer	•	ΔΡ	=	PxIB	-,		
		1	_B =	0.21			
		ΔP	=	2.5	t/m²		
Compression Index		Cc	***	0.12	.,		
Thickness of clay layer		Н	=	4.5	m		
Initial Void ratio		e _o	=	0.69			
		$\frac{\text{Po} + \Delta p}{\text{Po}}$	_ =	1.269662	9		
Settlement of clay layer		S_{f}	=	Cc 1+ eo	– н	log 10	$\frac{Po + \Delta I}{Po}$
			=	0.033	773		
		S _f	=	0.033	m		
Correction for Depth and Rigidity of fo Depth Factor Calculation	oundation	·	= = ement	33.13	m mm		
Correction for Depth and Rigidity of fo Depth Factor Calculation	oundation	on total settl					
Depth Factor Calculation	oundation	·		33.13			
	oundation	on total settl		33.13			
Depth Factor Calculation D = Depth of Foundation	oundation	on total settl	.5 =	33.13 0.61 2.67			
Depth Factor Calculation	oundation	on total settl D/(LB)^0 L/B	.5 = =	33.13 0.61 2.67 0.83	mm		
Depth Factor Calculation D = Depth of Foundation	•	on total settl D/(LB)^0 L/B	5 = = = ment o	33.13 0.61 2.67 0.83 f Rigid foun	mm	dation	_
Depth Factor Calculation D = Depth of Foundation Depth Factor	•	on total settl D/(LB)^0 L/B Total Settle	5 = = = ment o	33.13 0.61 2.67 0.83 f Rigid foun	mm	dation	_
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor =	• Total 9	on total settl D/(LB)^0 L/B Total Settle	5 = = = ment o	33.13 0.61 2.67 0.83 f Rigid foun	mm	dation	-
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Pore Pr. Correction=	• Total S	on total settl D/(LB)^0 L/B Total Settle	5 = = = ment o	33.13 0.61 2.67 0.83 f Rigid foundative of Flexil	mm dation ble found	dation	-
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor =	• Total 9	on total settl D/(LB)^0 L/B Total Settle	5 = = = ment o	33.13 0.61 2.67 0.83 f Rigid foun	mm dation ble found	dation	_



Settlement Calculation As per IS	8009 (Part 1	1)			Align	ment C	h. 186/0
BH No. (A1)							
Depth of foundation			=	4.5			
Length of footing (L)			-	8.0	m m		
Width of footing (B)			=	3.0	m		
Initial effective stress at mid of lay	yer	Po	-	12.02	t/m ²		
Concentrated load P	•		_	13.00			
Incerase in pressure at mid of laye	er	ΔΡ	=	P x I n	t/m ²		
. ,			I _B =	0.21			
		ΔΡ	_				
Compression Index		Cc	=	2.7	t/m ²		
Thickness of clay layer		Н	-	0.12			
Initial Void ratio			_	4.5	m		
	•	e ₀ Po + Δp		0.69 1.227216			
Sauth-read C. L. A.				Ca			_
Settlement of clay layer		S_f	=	1+ eo	- H	log 10	Po + A
		Sf	=	0.0284126	m		
Correction for Depth and Rigidity Depth Factor Calculation	of foundation		=	28.41	mm		
Correction for Depth and Rigidity Depth Factor Calculation	of foundation	on on total se	= ttlement	28.41			
Correction for Depth and Rigidity Depth Factor Calculation Depth of Foundation	of foundation		= ttlement	28.41			
Jepth Factor Calculation	of foundation	on on total se	= ttlement 0.5 =	28.41			
Jeptn Factor Calculation	of foundatio	on on total se	= ttlement 0.5 =	28.41 0.92 2.67			
Depth Factor Calculation D = Depth of Foundation	of foundation	D/(LB)^	= ttlement .0.5 = =	28.41 0.92 2.67 0.78	mm		
Depth Factor Calculation D = Depth of Foundation		D/(LB)^ L/B Total Settle	ttlement 0.5 = ement of	28.41 0.92 2.67 0.78	mm		
Depth Factor Calculation D = Depth of Foundation		D/(LB)^	ttlement 0.5 = ement of	28.41 0.92 2.67 0.78	mm	dation	
Depth Factor Calculation D = Depth of Foundation Depth Factor	Total	D/(LB)^ L/B Total Settle	ttlement 0.5 = ement of	28.41 0.92 2.67 0.78	mm	dation	
Depth Factor Calculation Depth of Foundation Depth Factor Rigidity Factor =	Total :	D/(LB)^ L/B Total Settle	ttlement 0.5 = ement of	28.41 0.92 2.67 0.78	mm	dation	
Depth Factor Calculation Depth of Foundation Depth Factor Rigidity Factor = Pore Pr. Correction=	Total	D/(LB)^ L/B Total Settle	ttlement 0.5 = ement of	28.41 0.92 2.67 0.78 Rigid foundate of Flexib	mm dation le found	dation	
Depth Factor Calculation Depth of Foundation Depth Factor Rigidity Factor =	Total :	D/(LB)^ L/B Total Settle	ttlement 0.5 = ement of	28.41 0.92 2.67 0.78	mm dation le found	dation	



Settlement Calculation As per IS 800	09 (Part 1)				Alignm	ent Ch.	186/0-1
BH No. (A1)	•						
Depth of foundation			=	6.0	m		
Length of footing (L)			=	8.0	m		
Width of footing (B)			=	3.0	m		
Initial effective stress at mid of layer		Po	=	14.11	t/m²		
Concentrated load P			=	14.00	t/m²		
Incerase in pressure at mid of layer		ΔP	=	PxIB	•		
•			/ _B =	0.21			
		ΔР	=	2.9	t/m²		
Compression Index		Cc	=	0.12	.,		
Thickness of clay layer		Н	=	4.5	m		
Initial Void ratio		e _o	=	0.69			
		Po + Δp Po	_ =	1.208399	8		
Settlement of clay layer		S _f	=	Cc 1+ eo	— н	log 10	Po + ΔI
	_	S _f	=	0.026268	5 m		
	•		=	26.27	mm		
Correction for Depth and Rigidity of a Depth Factor Calculation	foundation	on total set	tlement				
		D/(LB)	0.5 =	0.92			
D = Depth of Foundation							
D = Depth of Foundation		L/B		2.67			
D = Depth of Foundation Depth Factor		L/B		2.67			
D = Depth of Foundation Depth Factor		·	-	0.68			
·	Total :	Total Setti	= = ement o			dation	-
Depth Factor	Total !	Total Setti	= = ement o	0.68 f Rigid four		dation	-
Depth Factor		Total Setti	= = ement o	0.68 f Rigid four		dation	-
Depth Factor	= 0.8	Total Setti	= = ement o	0.68 f Rigid four		dation	-
Depth Factor Rigidity Factor =		Total Setti	= = ement o	0.68 f Rigid four ntre of Flexi	ble foun	dation	-
Depth Factor Rigidity Factor = Pore Pr. Correction=	= 0.8	Total Setti	= = ement o	0.68 f Rigid four	ble foun	dation	-



'ROR'

CHAPTER - 18

"RFO (ROR)",

Location - Existing Km. - 173/400



18.1 LOCATION OF STRUCTURE: Proposed RFO (ROR) No. 173/400

18.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 09.00m below EGL.

Subsurface profile at the site

BOREHOLE	Depth	Type of Soil/Rock	Soil/Rock
No.	(m)	- JP - 01 JOHN NOCK	Characteristics
	0.00 to 7.50	Silty Sand	Loose
	7.50 to 19.50	Silty Sand	Medium Dense
BH-1(A1)	19.50 to 22.50	Silty Sand	Dense
	22.50 to 28.50	Sand	Dense
	28.50 to 30.00	Sand	Very Dense
	0.00 to 1.50	Silty Sand	Loose
BH-2(A2)	1.50 to 16.50	Silty Sand	Medium Dense
	16.50 to 28.50	Silty Sand	Dense
	28.50 to 30.00	Sand	Dense

18.3 CHEMICAL ANALYSIS OF SOIL:

	MAD MINKE	OIO OI.	JOIL;										
BORE	HOLE	CHEMICAL PROPERTIES											
No.	Depth (m)	pН°	Carbonate	Chlorides %		Nitrate %	Salinity %						
	3.00	8.20	NIL	0.0017	NIL	0.0011	0.017						
BH-1 (A1)	9.00	7.80	NIL	0.0017	NIL	0.0011	0.017						
	18.00	8.10	NIL	0.0017	NIL	0.0011	0.019						
DVV 0 (10)	6.00	8.60	0.005	0.0017	NIL	0.0011	0.011						
BH-2 (A2)	12.00	7.90	NIL	0.0021	NIL	0.0011	0.039						
	21.00	8.20	NIL	0.0021	NIL	0.0011	0.034						

18.4 DIFFERENTIAL FREE SWELL INDEX (DES)

Bore Hole No.	Depth (m)	DFS Index in %
	3.00	NIL
BH-1(A1)	9.00	NIL
	18.00	NIL
	6.00	NIL '
BH-2 (A2)	12.00	NIL
•	21.00	NIL



18.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	_	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test	7.0	135	116	159	858	0.3	2.6	1032	1562
Result		}							
Requirement	Not	2000 for	400	200	3000	5 ml of	25 ml of	-	-
as per IS: 456	less	CC and				0.02	0.02		
/ Mosrth's	then	500 for				normal	normal		
	6.0	RCC				NaoH	H₂SO ₄		[

18.6 PILE LOAD CARRYING CAPACITY

18.6.1 Normal Bored Cast in-situ Pile Foundations:

Normal bored cast in situ RCC pile foundation is envisaged for the proposed bridge and have been analysed in the subsequent paragraphs. The Axial load carrying capacity of Pile in Rock is determined as per IRC-78: 2000 appendix-5.

The safe Load carrying capacities of piles have been worked out on the basis of IRC-78 as per provision/assumptions provided therein.. For calculating designed Capacity of pile recommendation of IS: 2911 should be followed. The minimum factor of safety on ultimate axial capacity should be as per clause 709.3.2 of IRC 78: 2000. The final design/construction of foundations, the safe /allowable load carrying capacity of these piles should be taken by conducting actual initial load tests on these piles casted in the respective area.

Further the piles should have necessary structural strength to transmit/sustain the design load.

Safe bearing capacity in t/m²

BH -NO.	DEPTH (mtr)	Net Allowable Bearing Pressure (t/m²)
	1.50	08.50
BH-1 (A1)	3.00	09.50
Dri-i (Ai)	4.50	11.50
	6.00	14.00
BH-2 (A2)	1.50	15.00
	3.00	16.00
	4.50	19.50

Geo-technical Investig	ation	Ludhiana	-Ambala Section (DFCCIL)	ROR No. 173/400
	6.00		21.00	

Pile load carrying capacity in t

BH -NO.	PILE DEPTH	PILE CARRYING CAPACITY IN TONNE
	(mtr)	Pile Diameter= 1.2 m
	17.00	225.00
BH-1 (A1)	20.00	290.00
	23.00	350.00
	17.00	225.00
BH-2 (A2)	20.00	290.00
	23.00	350.00

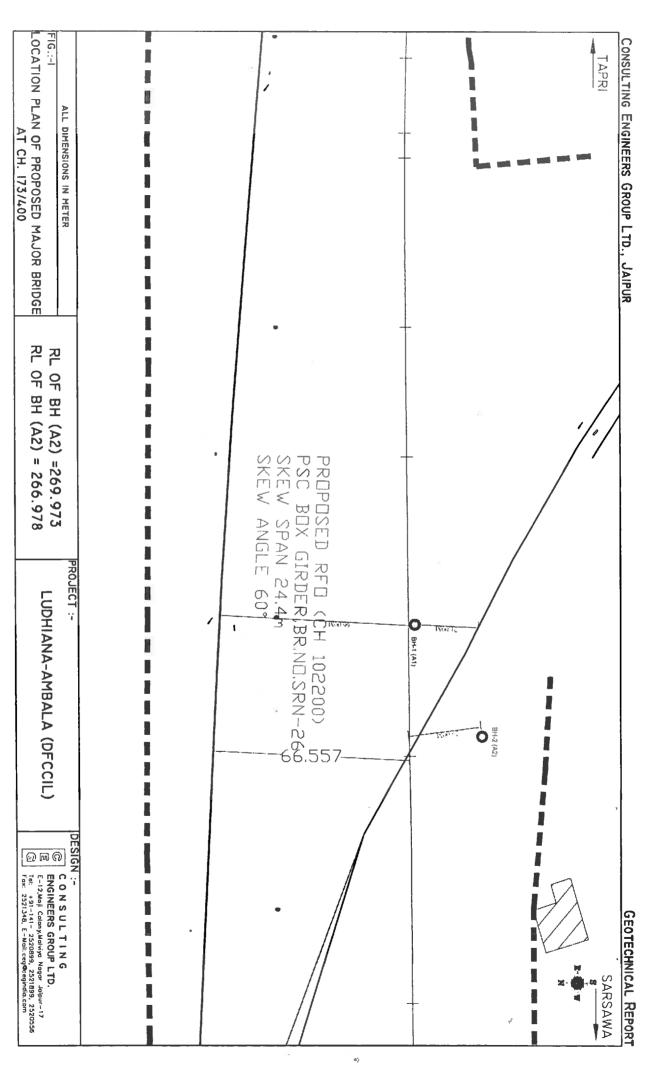
18.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

18.8 RECOMMENDATIONS

(i)_	Type of foundation	Pile foundation

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



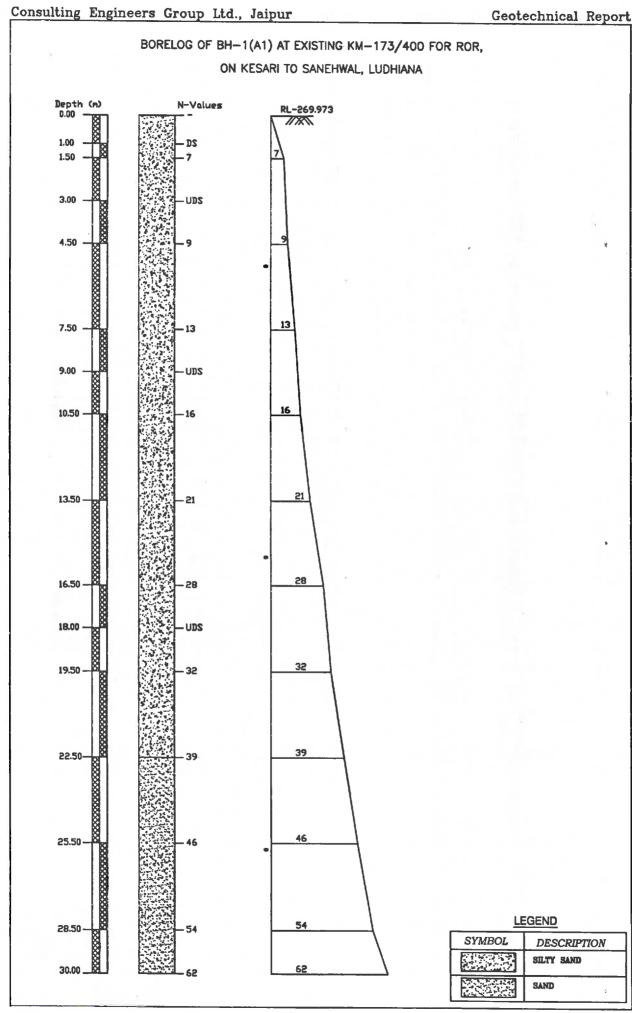
E-1

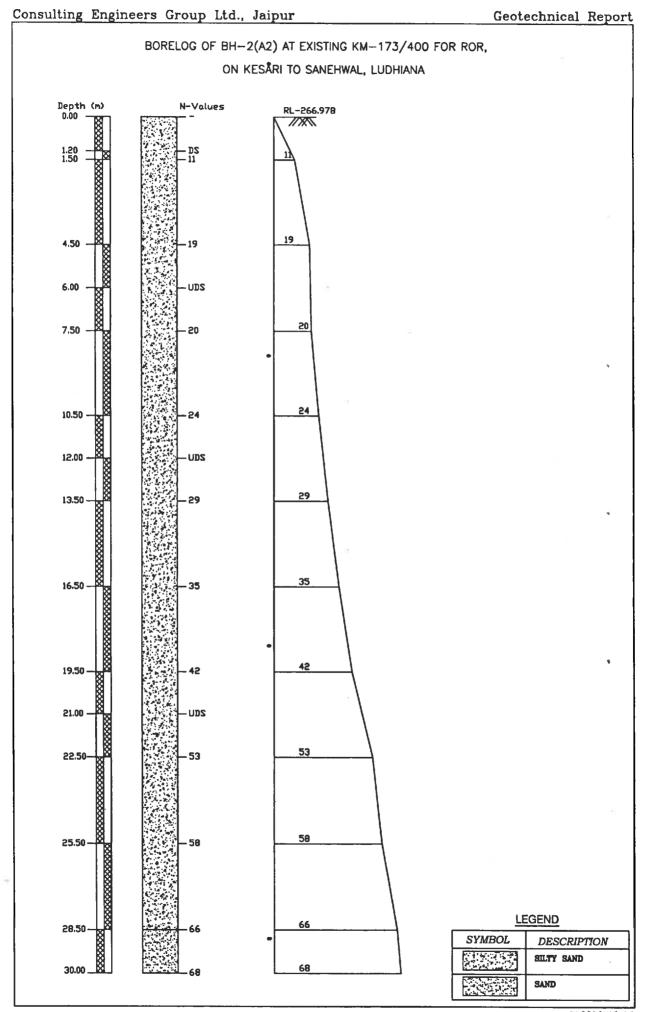
Geotechnical Report

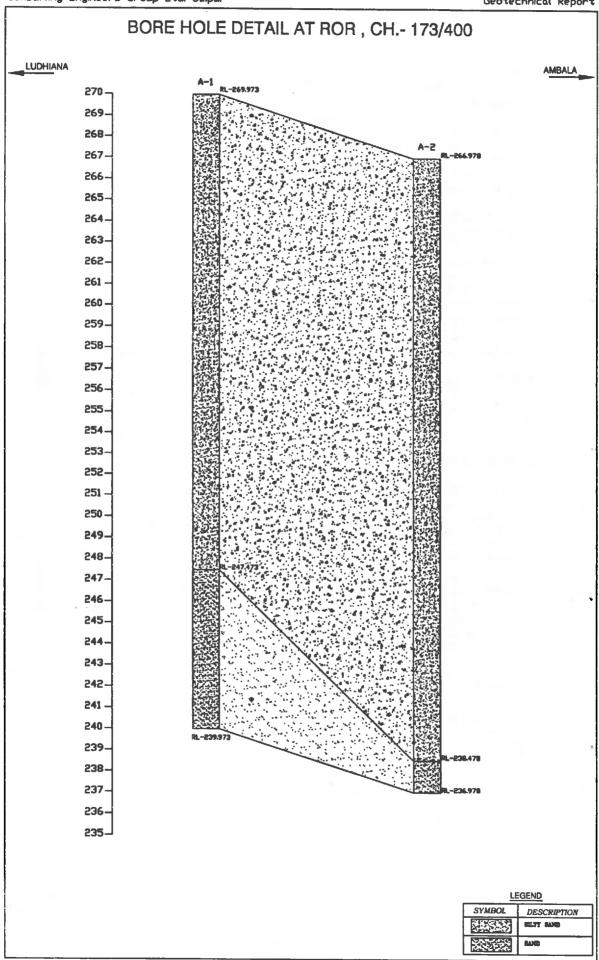
			ngth	•	degree			<u>.</u>	28.0	,		29.0				29.5						Engineers Group Ltd.
And the second state of th	5		Shear Strength		E KO/OH O		,		0:00		•	0.00				0.00	·			,		C O M S U
	Surface Elevation		Specific	Gravity			,		2.66		,	2.65				2.59	·	•	·	,)PC
9	Surfa		0.D		дш/сс	٠			1.57			1.59				1.72		,	١,			
173/4			M.C.		*				10.69	,		16.59	,	• :		17.28	,		٠	٠	•	
AGE			B.D.		gm/cc		٠		1.74	•	·	1.85		٠		2.02		٠	-	,		
CHAINAGE 173/400	Depth		ilts %		P.I.	ď.	NP.	ΔN	ď	₽ D	P.	ď	ď	Q.	NP	NP	NP	N.	Q.	ďΝ	ď	
	Termination Depth	30.00mtr	Atterberg Limits %		P.L	N L	NIL	N N	J.	Į	Į	N.	NIL	N N	N N	NIL	MIL	NIL	II.	ZIE	N.	
R) A	, E		Afte		크	82	23	56	53	27	82	28	72	28	30	24	25	31	59	92	92	
C(RC	r Table			Gravel	Coarse	0.00	00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
K RFC	Depth of Water Table	09.00 m.	2	Ğ	Fine	0.00	0.00	0.00	0.00	0.00	0.53	0.00	00.0	0.00	0.00	0.00	0.00	60.0	0.67	0.62	0.18	
FOR	Depth		M retained		Coarse	0.00	0.00	0.00	0.00	0.00	0.30	0.00	00:0	0.65	0.45	0.00	00.0	0.50	0.45	99.0	0.15	
AT BH-A1 FOR RFO (ROR) AT	9		Grain Size Distribution % wt	Sand	Medium	30.26	35.26	31.88	6.05	8.52	63.88	10.34	54.23	58.42	60.40	14.18	16.25	66.69	50.68	55.62	58.86	
	B.H. No.	-	Size Distri		Fine	62.35	58.52	58.57	88.08	90.6	29.84	78.17	36.20	32,56	31.58	75.92	75.26	25.60	45.41	40.36	36.85	
OLE	+	\vdash	Grain	-		7.39 6	6.22 5	9.55 5	5.87 8	8.20	5.45	10.93	9.57 3	8.37 3	7.57	9.90	8.49 7	3.82 2	2.79	2.74 44	3.98	
BORE HOLE	Location at	FA.		-			\vdash			-	\vdash	-						\vdash		_		
F BO	Ļ		_	Č	3	0.00	0.00	0.00	0.00	2.68	0.00	2.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	ī.
SOIL CHARACTERISTICS OF	Date of Testing	29.12.2009 to 30.12.2009	Soil	Description	(Soil Group)	Sify Sand	Silty Sand	Sifty Saft	Silty Sand	Silty Sand	Silly Sand	Salty Sand	Silly Sand	Silly Sand	Silty Sand	Silty Sand	Silty Sand	Sand	Sand	Sand	Sand	
L CHAR			Corrected		z,			10.01		9.63	11.70	٠	12.48	14.70	16.32	•	16.62	17.64	18.31	19.11	20.21	
SOI	inage 173/400	RFO (ROR) Bridge	Correction	Factor	້ບ		٠	1.43	,	1.07	0.90	٠	0.78	0.70	0.63		0.57	0.52	0.47	0.43	0.41	
	Cha	RFC	Observ-	pe pe	Z	•	SO	2	SON	Ch.	13	SON	16	21	28	SON	32	39	46	25	62	
CAN INCOME AND ADDRESS OF THE PARTY OF THE P		Project:	Depth	from	GL (m)	00.00	1.00	1.50	3.00	4.50	7.50	9.00	10.50	13.50	16.50	18.00	19.50	22.50	25.50	28.50	30.00	

			ngth	•	degree			•	•	29.0			29.5	,			28.5					Engineers Group Lid
,	ç		Shear Strength		D C ROYCH					00.00	,	•	0.00	,	,	•	0.00				,	Engineers
	Surface Elevation		Specific	Gravity			•	•	•	2.60		•	2.65	,	,	•	2.67		•	•		
90	Surfac		D.D.	J	дшусс	•	•	-	•	1.63	-	·	1.63	•	•	•	1.68	,	•	-	,	
173/4			M.C.		3¢	-			,	14.74	,	٠	16.43		,	•	18.66		•		•	
CHAINAGE 173/400			B.D.		да/сс	٠	•	•	-	1.87	•	٠	1.90	٠	٠		2.00	٠	-	•	•	
IAIN	Depth	ľ	rits %		P.I.	dN	NP	NP	NP	dΝ	dΝ	dN	ΝÞ	NP	ΝÞ	NP	ΝP	NP	ΔN	ΝÞ	N	
TCE	 Termination Depth	30.00mtr	Attendeng Limits		P.L.	NIL	MIL	NIL	NIL	NIL	NIL	NIL	(8									
R) A	 Tem		Atte		L.	ន	25	27	28	24	25	56	28	52	24	52	24	88	22	92	25	
) (RC	r Table	_		Gravel	Coarse	00.0	0.00	0.00	0.00	0.00	00:00	0.00	00.00	0.00	00.0	0.00	0.00	0.00	0.00	0.00	00.00	ir
RF(Depth of Water Table	09.60 m.	20	ອັ	Fine	0.68	0.48	0.24	2.60	0.00	00.0	0.00	2.86	0.77	0.69	1.15	0.98	1.15	0.85	1.13	1.02	
FOF	Depth		wt retain		Coarse	0.36	0.48	0.56	1.15	0.76	0.85	00.0	1.02	1.05	0.85	1.12	1.10	0.86	0.73	09.0	0.20	
SS OF BORE HOLE AT BH-A2 FOR RFO (ROR) AT	ġ.		Size Distribution % wt retained	Sand	Medium	10.52	8.35	6.80	38.66	4.49	60.35	62.30	5.15	24.35	28.53	30.42	53.64	58.43	62.15	64.35	47.44	
AT.	 B,H, No.	2	Size Distr		Fine	78.69	72.39	74.92	47.90	63.08	24.59	27.36	78.72	62.96	55.12	53.29	36.26	33.52	31.26	30.22	47.69	
HOLE	 _		Grain		Ĭ	9.75	14.61	13.22	9.69	28.26	10.96	6.18	8.67	7.21	12.66	14.02	8.02	6.04	5.01	3.70	3.65	
RE	 Location at	V 2		L	à S	0.00	_	_	H		-	-	_		2.15				-			
F BC					3	0	3.69	4.26	0.00	3.41	3.25	4.16	3.58	3.64	2.	0.00	0.00	0.00	0.00	0.00	0.00	
SOIL CHARACTERISTICS 0	Date of Testing	29.12.2009 to 29.12.2009	Soil	Description	(Soil Group)	Silty Sand	Sifty Sand	Silty Sand	Sifty Sand	Sand	Sand											
L CHAI		9	Corrected		ź	•		15.73	20.14	,	17.80	16.86	,	17.51	18.35	19.47		21.28	21.13	21.69	21.44	
IOS	inage 173/40	RFO (ROR) Bridge	Correction	Factor	ర్	,	·	1.43	1.06	·	0.89	0.78	·	0.69	0.62	0.57	٠	0.52	0.47	0.43	0.41	
	 Cha	RFC	Observ-	D 8	z	,	SO	11	19	san	8	24	Sau	53	35	42	san	23	58	99	99	
		Project :	Depth	from	GL (m)	0.00	1.20	1.50	4.50	9.00	7.50	10.50	12.00	13.50	16.50	19.50	21.00	22.50	25.50	28.50	30.00	

 \bigcirc







Calculation of SBC for shallow foundations as per IS: 6403 - 1981

INPUT DATA

		Ch 173-400	BH-A1	
Type of	f footing			
1	Continuous Strip		[
2	Rectangular		Rectangular	2
3	Square			
4	Circular			

Angle of internal friction (\$\phi^0\$)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.69
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m³)	1.70
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,i_c+q\;(N_{q^-}1)\;s_q\,d_q\,i_q+(1/2)\;B\;\gamma\,N_{\gamma}s_{\gamma}d_{\gamma}i_{\gamma}W'$

The ultimate net bearing capacity in case of local shear failure is given by $q_d' = (2/3) \ c \ N_c' s_c \ d_c \ i_c + q \ (N_{q} - 1) \ s_q \ d_q \ i_q + (1/2) \ B \ \gamma \ N_{\gamma}' s_{\gamma} \ d_{\gamma}' i_{\gamma} W'$

Where,

 $d_{c} = 1 + 0.2 (D_{l}/B)^{*}SQRT(N_{\phi})$

 $d_q = d_y = 1 \text{ for } \phi < 10^\circ$

 $d_q = d_y = 1 + 0.1 (D_r/B)^*SQRT(N_\phi) \text{ for } \phi > 10^\circ$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

of for local shear failure = tan⁻¹ (0.67 tano)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

ф	28.00
N _c	26.37
N _q	15.30
N _y	17.79

φ'	19.61
N'c	14.53
N' _q	6.21
N' _y	5.18

Shape factors:

S.no.	Width(m)	Length (m)	S _c	Sq	S,
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85
			•		

Depth factors:

1	1.50	3.00	1.17	1.08	1.08
2	3.00	3.00	1.33	1.17	1.17
3	4.50	3.00	1.50	1.25	1.25
4	6.00	3.00	1.67	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_a = (1-\alpha/90)^2$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _• /B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	35.28	12.33	19.22
2	3.00	3.00	8.00	37.99	13.28	20.69
3	4.50	3.00	8.00	40.70	14.23	22.17
4	6.00	3.00	8.00	43.41	15.18	23.65

Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 173 400	BH-A2		
Type	of footing				
1	Continuous Strip				1
2	Rectangular		Rectangular	2	ı
3	Square		_		ı
4	Circular				
Angle	of internal friction (¢°)			27.50)
Cohes	ion (c in t/m2)			0.00)
Void ra	atio (e)			0.70	

Angle of litternal motion (\$\phi\$)	27.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m3)	1.83
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_{d}=c\ N_{c}\ s_{c}\ d_{c}\ i_{c}+q\ (N_{q}\text{-}1)\ s_{q}\ d_{q}\ i_{q}+(1/2)\ B\ \gamma\ N_{\gamma}s_{\gamma}d_{\gamma}i_{\gamma}W'$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3) c N'_c s_c d_c i_c + q (N'_q-1) s_q d_q i_q + (1/2) B \gamma N'_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$$

Where,

 $d_c = 1 + 0.2 (D/B)*SQRT(N_e)$

 $d_q = d_y = 1$ for $\phi < 10^\circ$

 $d_q = d_{\gamma} = 1 + 0.1 (D_{\gamma}B)^*SQRT(N_{\phi}) \text{ for } \phi > 10^{\circ}$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

φ' for local shear failure = tan-1 (0.67 tanφ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.



Bearing capacity factors :

ф	27.50
N _c	25.43
Nq	14.53
N _y	16.64

φ'	19.23
N' _c	14.24
N' _q	6.02
N' _Y	4.97

Shape factors :

S.no.	Width(m)	Length (m)	Sc	s,	S,
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors:

1	1.50	Width(m) 3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.25	1.25
4	6.00	3.00	1.66	1.33	1.33

inclination factors:

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1 - \alpha / 90)^{2}$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z"/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00		-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)	_	
				General shea	Local shear	Actual
1	1.50	3.00	8.00	33.77	12.02	17.46
2	3.00	3.00	8.00	36.34	12.94	18.79
3	4.50	3.00	8.00>	38.91	13.85	20.12
4	6.00	3.00	8.00	41.48	14.77	21.44

Sett	Settlement Calculation As per IS 8009 (Part 1)					
Location	ROR					
Chainage	173/400					
Bore Hole No.	A1	_				

Footing Depth (m)	1.50
SBC (t/m2)	8.50
A	10.00
Average N value	10.00
	•
Settlement for 10 t/m2 (mm)	32.00
Total Settlement (mm)	27.20
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	24.8

Footing Depth (m)	3.00
SBC (t/m2)	9.50
Average N value	10.00
Settlement for 10 t/m2 (mm)	32.00
Total Settlement (mm)	30.40
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	25

Footing Depth (m)	4.50
SBC (t/m2)	11.50
Average N value	11.00
Settlement for 10 t/m2 (mm)	29.00
Total Settlement (mm)	33.35
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	24.3

Footing Depth (m)	6.00
SBC (t/m2)	14.00
Average N value	12.00
Settlement for 10 t/m2 (mm)	26,00
Total Settlement (mm)	36,40
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	24.8

Sett	lement Calculation As per IS	8009 (Part 1)
Location	ROR	
Chainage	173/400	
Bore Hole No.	A2	

Footing Depth (m)	1.50
SBC (t/m2)	15.00
Average N value	17.00
Settlement for 10 t/m2 (mm)	17.00
Total Settlement (mm)	25.50
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	23.2

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	19.00
Settlement for 10 t/m2 (mm)	14.00
Total Settlement (mm)	22.40
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	18.6

Footing Depth (m)	4.50
SBC (t/m2)	19.50
Average N value	19.00
Settlement for 10 t/m2 (mm)	14.00
Total Settlement (mm)	27.30
Depth Correction	0.78
Rigidity factor	0.8
Corrected Settlement (mm)	21.3

Footing Depth (m)	6.00
SBC (t/m2)	21.00
Average N value	19.00
Settlement for 10 t/m2 (mm)	14.00
Settlement for 10 ymz (mm)	14.00
Total Settlement (mm)	29.40
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	20.0

'ALIGNMENT'

CHAPTER - 17

"Major Bridge No. 210",

Location - Existing Km. - 172/03-04



17.1 LOCATION OF STRUCTURE:

Proposed Major Bridge of Span 4 x 30.50

17.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 08.00m below EGL.

Subsurface profile at the site

BOREHOLE	Depth	Type of Soil/Rock	Soil/Rock
No.	(m)	31	Characteristics
	0.00 to 4.50	Silty Sand	Loose
BH-1(A1)	4.50 to 19.50	Silty Sand	Medium Dense
	19.50 to 30.00	Silty Sand	Dense
	0.00 to 4.50	Silty Sand with Gravels	Loose
BH-2(P2) 4.50 to 16.50 16.50 to 30.00		Silty Sand	Medium Dense
		Silty Sand	Dense
	0.00 to 1.50	Silty Sand with Gravels	Loose
	1.50 to 16.50	Silty Sand	Medium Dense
BH-3(A2)	16.50 to 19.50	Sand	Medium Dense
	19.50 to 28.50	Sand	Dense
	28.50 to 30.00	Silty Sand	Dense

17.3 CHEMICAL ANALYSIS OF SOIL:

CHEMIC	CHEMICAL ANALYSIS OF SOIL;						
BOREHOLE			CI	HEMICAL	PROPERTI	ES	
No.	Depth (m)	pН	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
	3.00	8.20	NIL	0.0014	NIL	0.0011	0.012
BH-1 (A1)	12.00	8.40	NIL	0.0021	NIL	0.0012	0.088
	27.00	8.60	NIL	0.0022	NIL	0.0013	0.062
	3.00	8.10	NIL	0.0024	NIL	0.0012	0.074
BH-2 (P2)	9.00	9.70	0.010	0.0017	NIL	0.0012	0.053
	24.00	8.30	0.005	0.0021	NIL	0.0011	0.052
	3.00	8.20	NIL	0.0025	NIL	0.0011	0.055
BH-3 (A2)	12.00	8.60	0.005	0.0024	NIL	0.0011	0.058
	21.00	8.40	0.005	0.0020	NIL	0.0010	0.052

17.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
	3.00	NIL
BH-1(A1)	12.00	NIL
•	27.00	NIL



Geo-technical Investigation	Ludhiana-Ambala Section (DFCCIL)	Major Bridge No. 210
	3.00	NIL
BH-2(P2)	9.00	NIL
	24.00	NIL
577.54.5	3.00	NIL
BH-3(A2)	12.00	NIL
	21.00	NIL

17.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductiv ity (µS/cm)
Test Result	6.40	49	NIL	75	356	0.6	2.20	458	715
Requirement as per 15: 456 / Mosrth's		2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	-	-

17.6 PILE LOAD CARRYING CAPACITY

17.6.1 Normal Bored Cast in- situ Pile Foundations:

Normal bored cast in situ RCC pile foundation is envisaged for the proposed bridge and have been analysed in the subsequent paragraphs. The Axial load carrying capacity of Pile in Rock is determined as per IRC-78: 2000 appendix-5.

The safe Load carrying capacities of piles have been worked out on the basis of IRC-78 as per provision/assumptions provided therein. For calculating designed Capacity of pile recommendation of IS: 2911 should be followed. The minimum factor of safety on ultimate axial capacity should be as per clause 709.3.2 of IRC 78: 2000. The final design/construction of foundations, the safe /allowable load carrying capacity of these piles should be taken by conducting actual initial load tests on these piles casted in the respective area.

Further the piles should have necessary structural strength to transmit/sustain the design load.

Safe bearing capacity in t/m²

BH - NO.	DEPTH (mtr)	Net Allowable Bearing Pressure (t/m²)
	1.50	14.00
BH-1 (A1)	3.00	15.00
	4.50	16.00
	6.00	17.00



Geo-technical Investigati	ion	Ludhiana-Ambala Section (DFCCIL)	Major Bridge No. 210
	1.50	16.00	
DIV 0 (4.0)	3.00	17.00	
BH-3 (A2)	4.50	18.50	
	6.00	19.50	

Pile load carrying capacity in t

BH-NO.	PILE DEPTH	PILE CARRYING CAPACITY IN TONNE
	(mtr)	Pile Diameter= 1.2 m
	17.00	220.00
BH-1 (A1)	20.00	280.00
	23.00	345.00
	17.00	220.00
BH-2 (P2)	20.00	280.00
	23.00	345.00
	17.00	220.00
BH-3 (A2)	20.00	280.00
	23.00	345.00

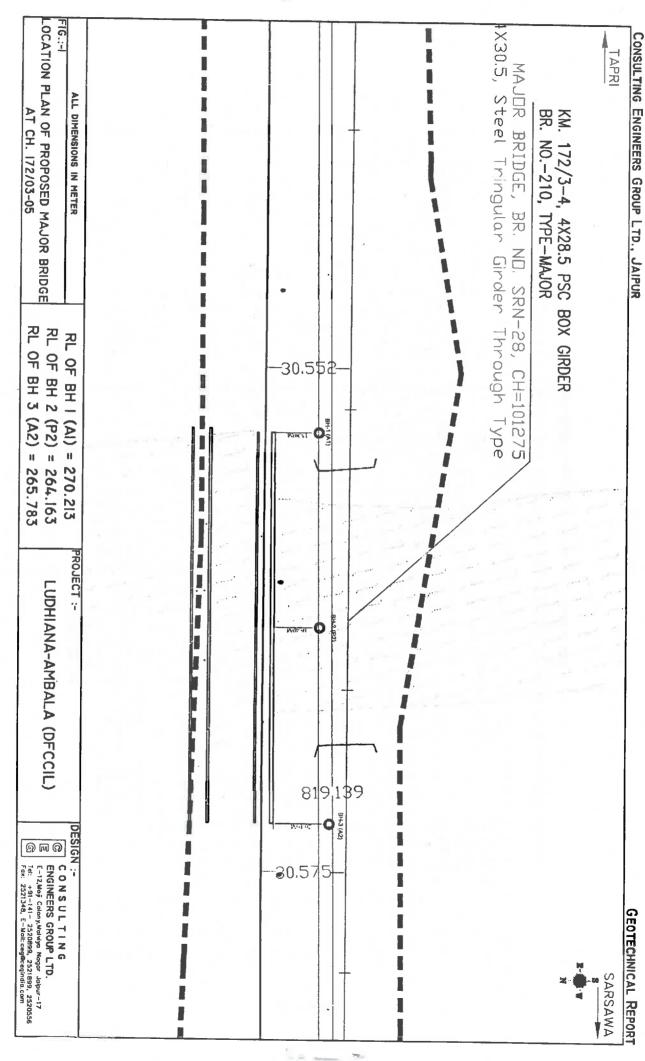
17.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

17.8 RECOMMENDATIONS

(i)	Type of foundation	Pile foundation

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



				į				•											T		25
			trength	•	degree		٠	27.0	· l	•		29.0	,	'	'	'	'	28.5			CONSULTING
	_		Shear Strength	, balom	3	•		0.00	,	•	٠	0.0					٠	0.0	•	٠	C O N
7	Surface Elevation		Specific	Gravity			٠	2.68	•	,	٠	5.66						2.67			
2/03-0	Surface		D.D.		аш/αс		٠	1.56	•		•	1.61	•	·	٠	,	,	1.62	·	·	
CHAINAGE 172/03-04			M.C.		₉₆			9.73			,	17.63	•	٠	٠	•		20.42	,		
INAC			B.D.		вш/сс		•	1.72	•	,	,	1.89			•		•	1.95	,	ı	
	epth		ts %		P.1.	<u>₽</u>	ď	ď	۵N	ďΝ	ď	ď	ďΝ	ďΝ	ď	<u>a</u>	ů Ž	ď	ů.	ď	
0 AT	Termination Depth	30.00mtr	Atterberg Limits		P.L.	NE	N.	NIL	NIL	JIN.	NIL	NBL	NIL	NIL	NIL	NIL	NE NE	MIL	MIL	N	
0.21	Теги		Atter		LL	25	26	28	26	25	27	26	28	29	27	25	26	25	27	28	
GEN	Table			Gravel	Coarse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SRID	Depth of Water Table	08.00 m.	0	g	Fine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	
IORI	Depth		wt retaine		Coarse	0.00	00:0	00:0	0.03	0.00	0.00	0.32	0.11	0.00	0.00	0.00	0.04	0.12	0.00	0.04	
* MA	ģ		Grain Size Distribution % wt retained	Sand	Medium	5.21	3.09	6.46	12.61	14.07	60.47	57.45	55.13	64.50	54.05	42.85	52.69	72.69	78.45	56.06	
BORE HOLE BH-A1 FOR MAJOR BRIDGE NO. 210 AT	B.H. No	-	Size Distri		Fine	90.36	83.46	84.55	77.93	72.31	33.82	36.26	38.97	30.28	40.68	50.48	42.64	16.38	15.87	39.07	
BH-A	ta ta		Grain	<u> </u>	 ā	11.57	10.31	8.99	9.43	10.37	5.71	2.97	5.79	5.22	5.27	6.67	4.63	10.81	5.68	4.65	
OLE	Location at	¥		-	<u> </u>	2.86	3.14	00:0	0.00	3.25	00.00	00:00	00.0	0.00	0.00	0.00	0.00	0.00	00:00	0.00	
RE H	-			_		2	e .	°	°	F	0	-	-	•	°	0	•	-	•	0	
SOIL CHARACTERISTICS OF BO	Date of Testing	25.12.2009 to 26.12.2009	Soil	Description	(Soil Group)	Silty Sand	Sifty Sand	Silty Sand	Silty Sand	Sity Sand	Sifty Sand	Salty Sand	Silty Sand	Sifty Sand	Sifty Sand	Silty Sand					
ARACT	4		Corrected		ž		11.44		14.84	15.13	14.82		15.90	16.64	16.91	16.86	17.10		18.06	19.47	
OIL CH	Chainage 172/03-04	Bridge No. 210	Correction	Factor	౮		1.43	·	1.06	0.89	97.0		0.70	0.63	0.57	0.52	0.48		0.44	0.42	
S	Chair	à	Observ-	8	z		60	San	14	17	19	Sau	24	53	33	36	04	SON	48	25	
		Project :	Depth	from	GL (m)	0.00	1.50	3.00	4.50	7.50	10.50	12.00	13.50	16.50	19.50	22.50	25.50	27.00	28.50	30.00	

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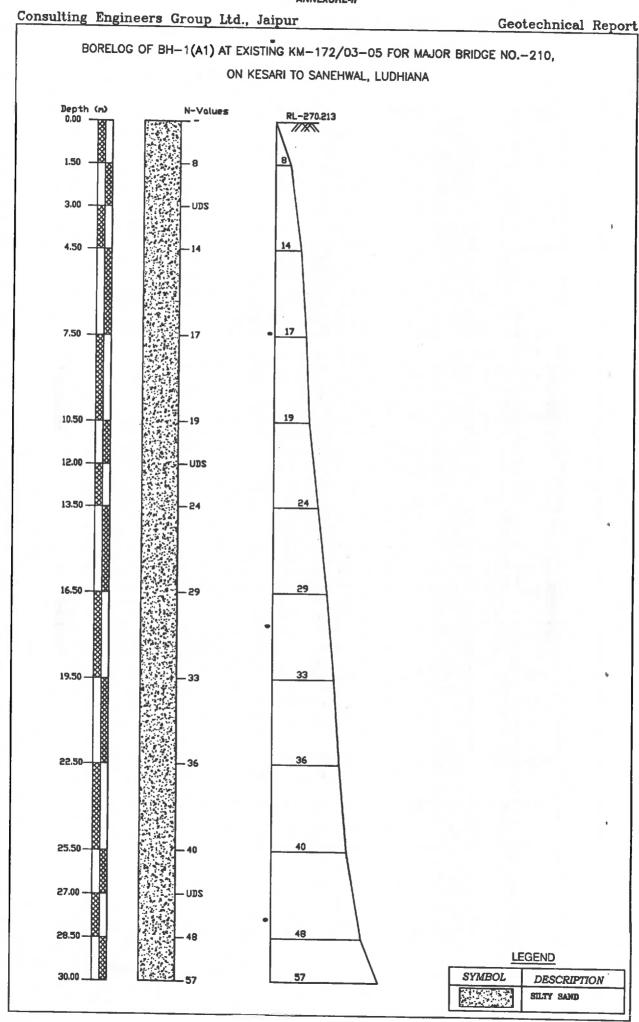
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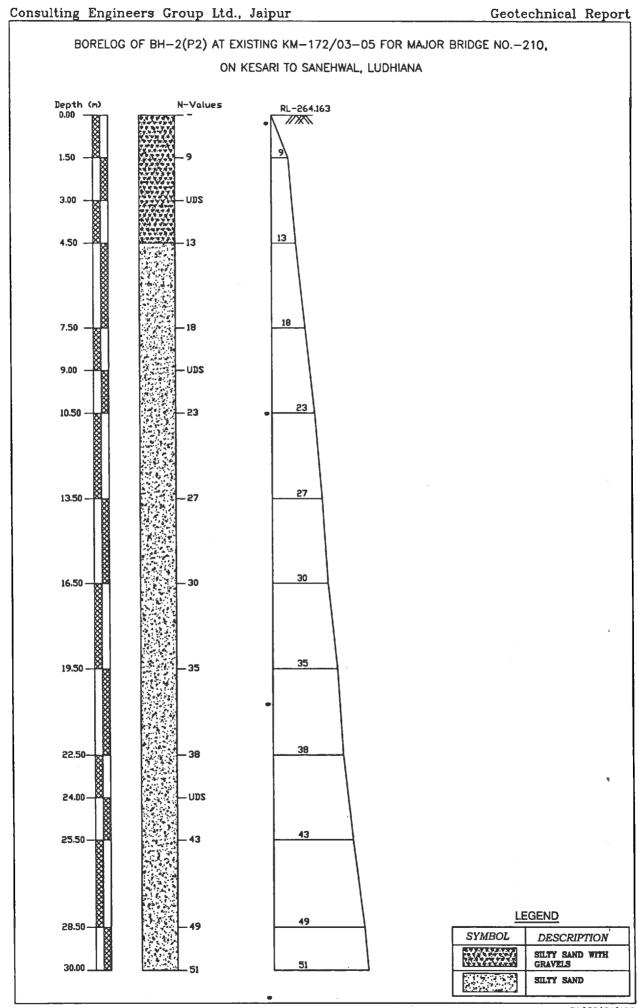
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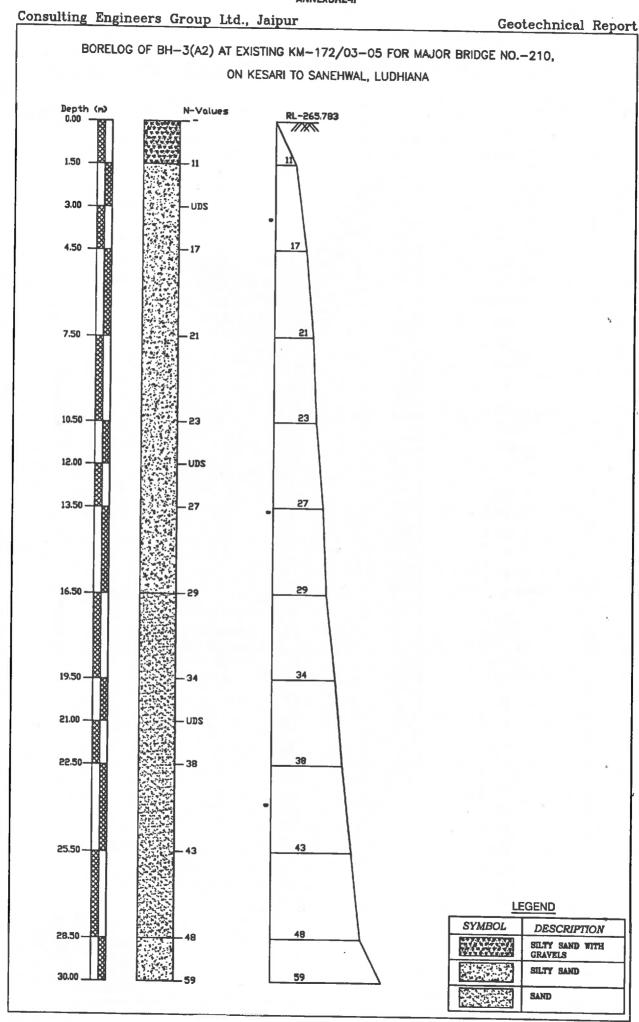
Geotechnical Report

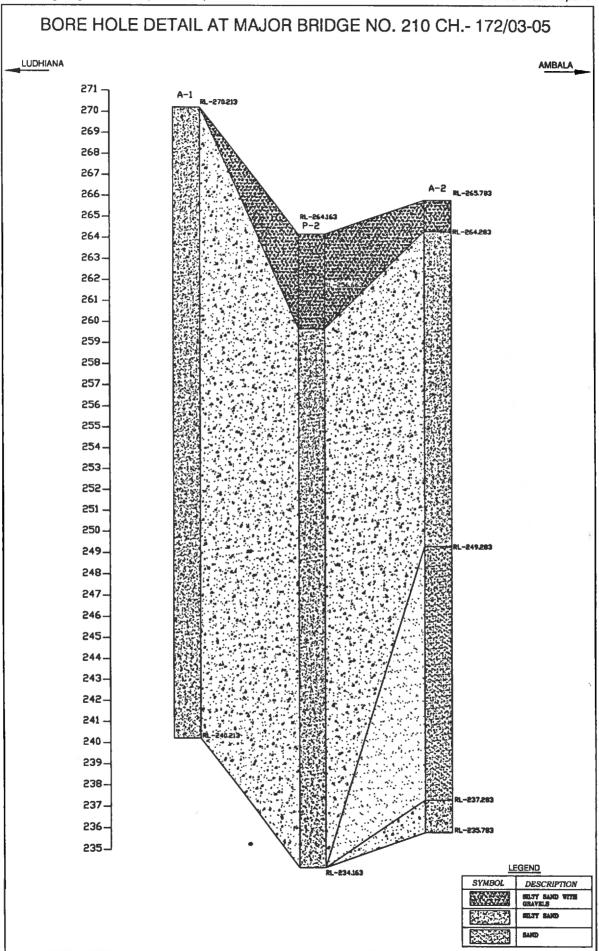
	IOS	CHA	KACT'E	SOIL CHARACTERISTICS OF BORE HOLE	HOLE	A	77-11	BH-F2 FOR MAJOR			DALLOGE INO. 210 A1		7 017		TAIL	AGE		CHAINAGE 1/2/03-04		
	Chai	Chainage 172/03-04	\$	Date of Testing	Local	Location at	8	B.H. No.	Depth	Depth of Water Table	r Table	I I	Fermination Depth	apth			Surface	Surface Elevation		
rioject .	ã	Bridge No. 210		27.12.2009 to 28.12.2009		22		2		06.00 m.			30.00mtr	1						
Depth	Observ-	Correction	Corrected	Soil	-	Grain	in Size Di	Size Distribution % wt	wt retained	, p		Atte	Atterberg Limits	%	B.D.	M.C.	D.D. S	Specific SI	Shear Strength	f)
trom	90	Factor		Description	į	4.0		Sand		Ö	Gravel						0	Gravity		•
GL (m)	z	ర్	ž	(Soil Group)	Ciay	O. C.	Fine	Medium	Coarse	Fine	Coarse	4	P. Li	F.	дш/сс	%	ээ/шб	<u> </u>	c kg/cm/	degree
00.0	•	٠.	٠	Silty Sand with Gravels	3.68	31.86	42.32	11.52	2.36	8.26	0.00	æ	Ę	ě						
1.50	6	1.45	13.05	Silty Sand with Graveis	4.15	34.06	40.37	9.25	2.05	10.12	0.00	22	Ę	ů.	•	,			,	'
3.00	nds	,		Silty Sand with Gravels	3.84	14.06	57.48	5.91	3.33	15.38	0.00	83	Į.	d N	1.77	10.41	99.	2.64	0.00	29.5
4.50	13	1.08	14.04	Sifty Sand	2.65	9.24	62.86	22.66	0.77	1.82	0.00	ង	Ĭ	2						
7,50	18	0.91	15.69	Sitty Sand	0.00	8.25	74.50	16.34	0.21	0.70	0.00	83	¥	2						
9.00	San			Silty Sand	0.00	7.91	39.59	52.50	0.00	0.00	0.00	28	Ę	å.	1.86	16.69	55.	2.72	0.0	28.5
10.50	ន	0.79	16.59	Sifty Sand	0.00	6.75	32.92	60.33	0.00	0.00	0.00	27	I	ā.						١.
13.50	27	0.70	16.95	Sifty Sand	0.00	7.70	43.23	49.07	0.00	0.00	0.00	28	NIL	Ğ.	,	,				
16.50	80	0.63	16.95	Sifty Sand	0.00	5.58	37.51	56.91	0.00	0.00	0.00	27	NIL	ď	•					
19.50	35	0.58	17.65	Silty Sand	0.00	6.20	64.35	29.38	0.07	0.00	0.00	27	NIL	ď	<u> </u>	,	,		,	٠.
22.50	38	0.53	17.57	Silty Sand	0.00	5.83	46.75	47.42	0.00	0.00	0.00	27	NIL	ď	•	•				٠.
24.00	San	•	1	Sitty Sand	0.00	7.56	24.70	67.75	0.00	00.0	0.00	28	NI NI	d.	1.92	18.23	1.62	2.66	0.0	29.0
25.50	43	0.48	17.82	Sity Sand	0.00	5.96	28.36	65.68	0.00	0.00	0.00	92	NIL	Š	,	,		,		
28.50	49	0.45	18.53	Silty Sand	00.00	7.42	28.32	64.26	0.00	0.00	0.00	82	NIL	ď	•	,		•		٠.
30.00	51	0.42	18.21	Sifty Sand	0.00	9.24	28.32	59.89	0.84	1.71	0.00	92	NIC	NP.		,		•		
																		OPP.	Engineers Group Lid.	roup L
													:							

		Γ	l			<u> </u>	Γ	<u> </u>			Γ		Ι		_			Г	_		_	0 41111
				rength	•	degree		·	27.5				29.0		·		23.0		ŀ			Engineers Group Lid.
		ion		Shear Strength	-	c kocm	'	·	0.00	,			0.00			,	0.00					Engineer S
/03-0		Surface Elevation		Specific	Gravity				2.67		١.	٠.	2.64				2.66	'			,	Sec.
E 172		Surfa		D.D.		дш/сс	٠	·	1.56				1.73		·		1.72	·				
VAG				ĭ.C.		yę.	٠.		89.6		,		15.66				18.36		,	,		
HAI				B.D.		дш/сс	·	,	1.71				2.00	,	·		2.03			•		
VTC		epth		% 21		<u></u>	ě	ď.	ď	ě	₫.	å	ğ	g.	호	ď	ď	٩	٩N	ďΝ	Q. Ž	
210 /		Termination Depth	30.00mtr	Atterberg Limits		P.L.	Ę	Į,	Ę	뒫	¥	¥	Ę	Ę	륃	J	HZ HZ	Ę	J.	N N	Ę	
NO.		Term		Attent		4	52	27	82	52	27	28	24	82	22	56	25	28	28	53	56	
DGE		Table			vel	Coarse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
R BRU		Depth of Water Table	08.00 m.		Gravel	Fine	6.25	0.00	8.0	0.00	0.00	0.0	0.00	0.00	0.00	0.00	00.0	0.00	0.00	0.00	0.00	
AJOR		Depth		vt retained		Coarse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.0	90.0	0.00	
RE HOLE AT BH-A2 FOR MAJOR BRIDGE NO. 210 AT CHAINAGE 172/03-04		٥		Grain Size Distribution % wt retained	Sand	Мефит	8.62	6.24	8.52	6.35	5.40	47.21	4.35	45.42	46.65	57.72	60.42	62.60	32.95	50.65	55.28	
A2 F		B.H. No.	က	ize Distril		Fine N	77.39	83.78	78.48	80.35	81.57	47.55	79.53	47.81	48.40	38.25	35.42	33.02	61.70	42.66	38.99	
r BH-		=		Grain S	#:0		7.74 7	9.98	10.41	10.05	10.55 8	5.24 4	12.48 7	6.77 4	4.95	4.03	4.16 3	4.38	5.28 6	6.64 4	5.73 a	
E A7		Location at	P								-	H	_		-							
HOI			_		Š	5	0.00	0.00	2.59	3.25	2.48	0.00	3.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SOIL CHARACTERISTICS OF BORE		Date of Testing	26.12.2009 to 27.12.2009	Soil	Description	(Soil Group)	Siity Sand with Gravels	Sitty Sand	Silty Sand	Sifty Sand	Silty Sand	Sitty Sand	Sitty Sand	Silty Sand	Sand	Sand	Sand	Sand	Sand	Silty Sand	Sifty Sand	
ACTER		75		Corrected		ž	•	15.84	-	18.19	18.90	16.59		16.82	16.49	17.02		17.19	17.61	17.82	19.60	
CCHA		Chainage 172/03-04	Bridge No. 210	Correction	Factor	ບໍ	٠	1.44	•	1.07	06.0	0.79	•	69.0	0.62	0.56	•	0.51	0.47	0.43	0.41	
SOII		Chair	5	Observ-	pe	Z		11	Sau	17	21	23	uos	27	239	æ	NDS	38	43	48	58	
			riojeci :	Depth	from	GL (m)	0.00	1.50	3.00	4.50	7.50	10.50	12.00	13.50	16.50	19.50	21.00	22.50	25.50	28.50	30.00	









Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

	Ch 172 3-5	BH-A1	
Type of footing			
1 Continuous Strip			
2 Rectangular		Rectangular	2
3 Square		•	-
4 Circular			
Angle of internal friction (¢°)			27.00
Cohesion (c in t/m2)			0.00
Void ratio (e)			0.72
Direction of load with vertical (°)			0.00
Density of surcharge (I/m³)			1.70
Density of foundation soil (t/m3)			1.70
Depth of water table(m)			1.50

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Factor of safety

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d = c N_c s_c d_c i_c + q (N_q-1) s_q d_q i_q + (1/2) B \gamma N_s s_s d_s i_s W^*$

The ultimate net bearing capacity in case of local shear failure is given by $q'_{d} = (2/3) \; c \; N'_{c} \, s_{c} \, d_{c} \, i_{c} + q \; (N'_{q} - 1) \; s_{q} \, d_{q} \, i_{q} + (1/2) \; B \; \gamma \, N'_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_o)$ $d_q = d_y = 1 \text{ for } \phi < 10^\circ$ $d_q = d_\gamma = 1 + 0.1 \; (D/B)^* SQRT(N_\phi) \; \; \text{for} \; \phi > \! 10^\circ$ $N_0 = \tan^2(\pi/4 + \phi/2)$ of for local shear failure = tan-1 (0.67 tano)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

3.00

Bearing capacity factors :

ф	27.00
N _c	24.49
Nq	13.76
N _y	15.49

φ'	18.85
N' _c	13.94
N' _q	5.83
N' _y	4.76

Shape factors:

S.no.	Width(m)	Length (m)	S _c	S _a	S,
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d _a	d,
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.24	1.24
4	6.00	3.00	1.65	1.33	1.33

Inclination factors:

$i_c = (1 - \alpha / 90)^2$	$i_{\alpha} = (1 - \alpha / 90)^2$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z_/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	31.27	11.41	14.39
2	3.00	3.00	8.00	33.62	12.27	15.48
3	4.50	3.00	8.00	35.98	13.14	16.56
4	6.00	3.00	8.00	38.34	14.00	17.65



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 172 3-5	BH-A2	
Type o	of footing			
1	Continuous Strip		Г	
2	Rectangular		Rectangular	2
3	Square			•
4	Circular		- L	
	of internal friction (¢°)			27.50
Cohes	ion (c in t/m2)			0.00
Void ra	itio (e)			0.71
Direction	on of load with vertical (°)			0.00
Density	y of surcharge (t/m³)			1.70
Density	y of loundation soil (t/m3)			1.70
Depth	of water table(m)			1.50
Factor	of safety			3.00

S.no.	Depth (m)	Width (m)	Length (m
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00
4	6.00	3.00	

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d = c \; N_c \, s_c \, d_e \, i_e + q \; (N_{q}\text{-}1) \; s_q \, d_q \, i_q + (1/2) \; B \; \gamma \, N_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$

The ultimate net bearing capacity in case of local shear failure is given by $q'_d=(2/3)~c~N'_e\,s_c~d_c~i_e+q~(N'_q-1)~s_q~d_q~i_q+(1/2)~B~\gamma~N'_\gamma s_\gamma d_\gamma i_\gamma W'$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_a)$

 $d_q = d_\gamma = 1$ for $\phi < 10^\circ$

 $d_q = d_\gamma = 1 + 0.1 (D/B)^*SQRT(N_\phi) \text{ for } \phi > 10^\circ$

 $N_{+} = \tan^{2}(\pi/4 + \phi/2)$

of for local shear failure = tan-1 (0.67 tano)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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Bearing capacity factors ;

ф	27.50
N _c	25.43
N _q	14.53
N ₇	16.64

ł	φ'	19.23
ı	N'c	14.24
ł	N' _q	6.02
I	N' _y	4.97

Shape factors :

S.no.	Width(m)	Length (m)	Sc	· S _q	S,
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	•	dc	dq	d,
1	1.50	3.00		1.16	1.08	1.08
2	3.00	3.00		1.33	1.16	1.16
3	4.50	3.00		1.49	1.25	1.25
4	6.00	3.00		1.66	1.33	1.33

inclination factors :

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1-\alpha/90)^{2}$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

		Width(m)	Z"/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	33.27	11.87	16.15
2	3.00	3.00	8.00	35.80	12.78	17.38
3	4.50	3.00	8.00	38.34	13.68	18.61
4	6.00	3.00	8.00	40.87	14.58	19.84



ANNEXURE - IV

S	Settlement Calculation As per IS 8009 (Part 1)					
Location	Major Bridge					
Chainage	172/03-05					
Bore Hole No.	A1					

Footing Depth (m)	1.50
SBC (t/m2)	14.00
Average N value	13.00
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	33.60
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	24.5

Footing Depth (m)	3.00
SBC (t/m2)	15.00
Average N value	14.00
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	31.50
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	20.9

Footing Depth (m)	4.50
SBC (t/m2)	16.00
	•
Average N value	15.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	28.80
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	16.8

Footing Depth (m)	6.00
SBC (t/m2)	15.00
эвс (уши)	17.00
Average N value	15.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	30.60
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	16.6

ANNEXURE - IV

S	Settlement Calculation As per IS 8009 (Part 1)				
Location	Major Bridge				
Chainage	172/03-05				
Bore Hole No.	A2				

Footing Depth (m)	1.50
SBC (t/m2)	16.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	17.00
Total Settlement (mm)	27.20
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	19.8

Footing Depth (m)	3.00
SBC (t/m2)	17.00
Average N value	18.00
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	25.50
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	16.9

Footing Depth (m)	4.50
SBC (t/m2)	18.50
Average N value	10.00
Average IV value	18.00
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	27.75
()	•
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	16.2

Footing Depth (m)	6.00
SBC (t/m2)	19.50
Average N value	18.00
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	29.25
Depth Correction	0.67
Rigidity factor	0.8
Corrected Settlement (mm)	15.7

CHAPTER - 16

"Major Bridge No. 219",

Location - Existing Km. - 179/31-37



16.1 LOCATION OF STRUCTURE:

Proposed Major Bridge of Span 3 x 24.40

16.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.

(f) Depth of water Table 07.0m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
	0.00 to 1.50	Filled up Strata	Loose
	1.50 to 3.00	Silty Sand with Gravels	Medium Dense
BH-1(A1)	3.00 to 12.00	Silty Sand	Medium Dense
_(/	12.00 to 13.50	Sandy Silt with Clay	Medium Dense
	13.50 to 16.50	Silty Sand	Medium Dense
	16.50 to 30.00	Silty Sand	Dense
	0.00 to 1.50	Filled up Strata	Loose
1	1.50 to 7.50	Silty Sand	Loose
BH-2(P1)	7.50 to 22.50	Silty Sand	Medium Dense
-()	22.50 to 24.00	Silty Sand	Medium Dense
_	24.00 to 25.50	Silty Sand with Gravels	Dense
	25.50 to 30.00 °	Silty Sand	Dense
	0.00 to 3.00	Filled up Strata	Loose
	3.00 to 4.50	Sand	Loose
BH-3(A2)	4.50 to 12.00	Sand	Medium Dense
<u>_</u>	12.00 to 16.50	Silty Sand	Medium Dense
	16.50 to 30.00	Silty Sand	Dense

16.3 CHEMICAL ANALYSIS OF SOIL:

BORE	HOLE	CHEMICAL PROPERTIES						
No.	Depth (m)	pН	pH Carbonate Chlorides Sulphate Nitrate					
	3.00	8.70	0.005	%	<u>%</u>	%	%	
BH-1 (A1)	12.00	8.50	0.003	0.0025	NIL	0.0011	0.0033	
	27.00	8.60	NIL	0.0021	NIL	0.0011	0.028	
	3.00	8.10	NIL	0.0022 0.0014	NIL	0.0013	0.0041	
BH-2 (P1)	9.00	7.90	NIL	0.0014	NIL NIL	0.0011	0.043	
	24.00	8.20	NIL	0.0024	NIL	0.0012	0.059	
BH-3 (A2)	12.00	8.40	NIL	0.0017	NIL	0.0012	0.051	
				0.0017	TATE	0.0011	0.030	



Geo-technical Investigation		Ludh	iana-Ambala Se	ection (DFCCIL)	Ма	jor Bridge No.	219
	21.00	8.50	NIL	0.0021	NIL	0.0012	0.0033

16.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
	3.00	NIL
BH-1(A1)	12.00	NIL
	27.00	NIL
	3.00	NIL
BH-2 (P1)	9.00	NIL
	24.00	NIL
BH-3 (A2)	12.00	NIL
	21.00	NIL

16.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties		Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit		Alkalinity (ml)		Conducti vity (µS/cm)
Test Result	7.0	138	110	153	710	0.3	2.8	870	1349
Requirement as per 15:456 / Mosrths		2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	-	-

16.6 PILE LOAD CARRYING CAPACITY

16.6.1 Normal Bored Cast in- situ Pile Foundations:

Normal bored cast in situ RCC pile foundation is envisaged for the proposed bridge and have been analysed in the subsequent paragraphs. The Axial load carrying capacity of Pile in Rock is determined as per IRC- 78: 2000 appendix-5.

The safe Load carrying capacities of piles have been worked out on the basis of IRC-78 as per provision/assumptions provided therein.. For calculating designed Capacity of pile recommendation of IS: 2911 should be followed. The minimum factor of safety on ultimate axial capacity should be as per clause 709.3.2 of IRC 78: 2000. The final design/construction of foundations, the safe /allowable load carrying capacity of these piles should be taken by conducting actual initial load tests on these piles casted in the respective area.

Further the piles should have necessary structural strength to transmit/sustain the design load.

Safe bearing capacity in t/m²

BH - NO.	DEPTH (mtr)	Net Allowable Bearing Pressure (t/m²)
	1.50	15.00
BH-1 (A1)	3.00	16.00
	4.50	18.00
	6.00	19.00
	3.00	11.00
BH-3 (A2)	4.50	12.00
	6.00	12.50

Pile load carrying capacity in t

BH-NO.	PILE DEPTH	PILE CARRYING CAPACITY IN TONNE
	(mtr)	Pile Diameter= 1.20 m
	17.00	215.00
BH-1 (A1)	20.00	275.00
	23.00	340.00
	17.00	190.00
BH-2 (P1)	20.00	240.00
	23.00	300.00
	17.00	190.00
BH-3 (A2)	20.00	240.00
	23.00	300.00

16.7 CONCLUSIONS

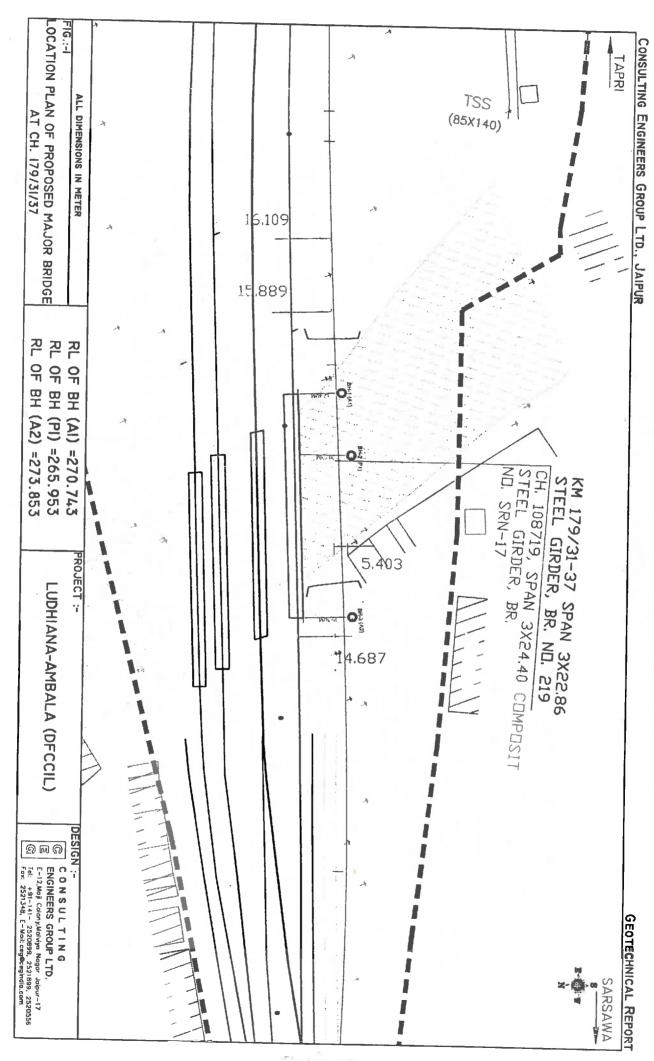
- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.



16.8 RECOMMENDATIONS

(i)	Type of foundation	Pile foundation	_

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



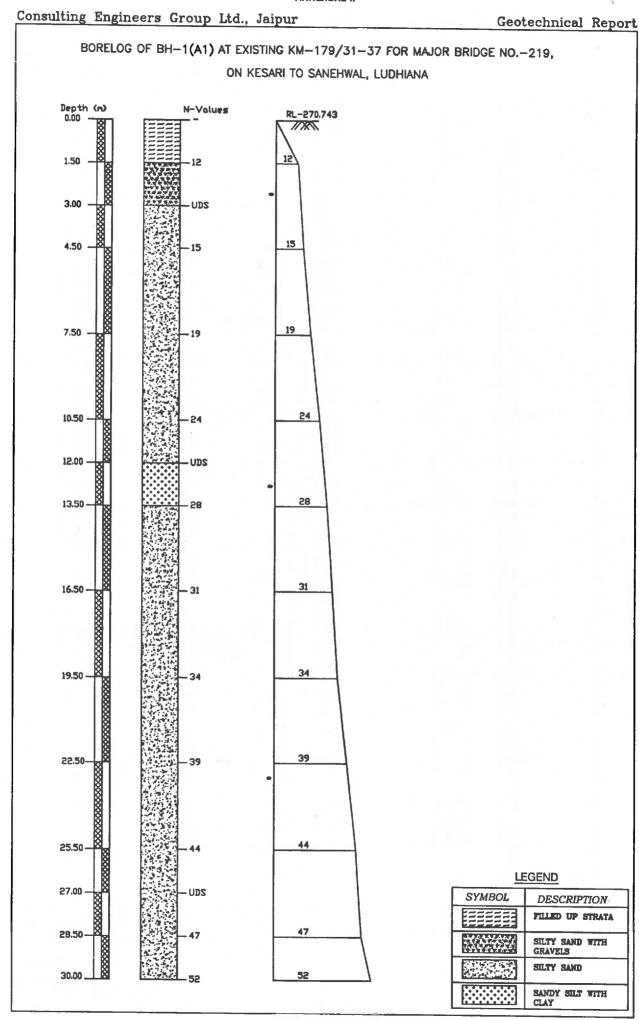
									 							ļ			
Project :	Chai	Chainage 179/31-37	-37	Date of Testing	Loca	Location at	ei —	B.H. No.	Dept	Depth of Water Table	r Table	Term	Termination Depth	pth		. "	Surface Elevation	evation	
	a a	Bridge No. 219		22.12.2009 to 23.12.2009		¥.		-		07.00 m.		L	30.00mtr						
Depth	Observ-	Correction	Corrected	Soil		Ğ	ain Size [Grain Size Distribution % wt retained	% wt retair	pa		Attent	Atterberg Limits	8	B.D.	M.C.	D.D. Specific		Shear Strength
from	6 0	Factor		Description			_	Sand		Ö	Gravel			-	\vdash		Gravity		L.
GL (m)	z	ບ ໍ	Z,	(Soil Group)	Š S	ਤੱ 	Fig	Medium	Coarse	Fine	Coarse	4	٦.	1.4 1.4	gm/œ	8	gm/cc	c kg/cm²	de de
0:00		٠	•	Filled up Strata	·	Ŀ	'			ŀ						1	-	.	Ľ
1.50	12	1.43	17.16	Sifty Sand with Gravels	0.00	9.41	35.37	45.71	1.86	7.65	0.00	22	¥	a ž	+				ļ.
3.00	San	•		Silty Sand	3.62	18.10	59.06	18.94	0.15	0.13	0.00	ж	¥	a Z	1.74	8.85	1.59 2.70	0.00	28.5
4.50	15	1.06	15.90	Sifty Sand	2.85	15.40	60.52	20.62	0.35	0.26	0.00	24	į	d Z		'	-		'
7.50	61	0.89	15.96	Silty Sand	4.35	223	58.07	32.12	0.23	0.00	0.00	83	불	9	-		<u> </u>	ļ ·	ļ.
10.50	24	0.78	16.86	Silty Sand	3.76	6.76	34.28	54.31	0.21	0.70	00.0	8	Z Z	d N	-		<u> </u>	·	<u> </u>
12.00	san	,	٠	Sandy Silt with Clay	9.28	69.11	14.45	4.57	0.75	1.86	0.00	78	P	80	1.96	18.38	1.65 2.67	0.09	21.0
13.50	88	69.0	17,16	Sifty Sand	286	20.35	52.82	22.04	1.18	0.75	9:00	8	불	ď	+	-	'	<u> </u>	Ľ
16.50	31	0.62	17.11	Silty Sand	3.52	8.20	60.45	26.08	0.11	2.	0.00	20	Ę	ā.	+.	+	<u> </u>	•	
19.50	8	0.56	17.02	Silty Sand	4.12	9.88	49.66	35.08	1.26	1.00	0.00	22	불	<u>a</u>	+	-	.		Ľ.
22.50	39	0.52	17.64	Silty Sand	3.49	11.51	57.19	27.71	0.10	0.00	0.00	83	륃	₫.	-	·	.	<u> ·</u>	ļ.
25.50	1	0.47	17.84	Silty Sand	3.69	10.09	44.75	40.85	0.37	0.25	0.00	8	N N	a Z	 	'	ļ.	١.	ļ.
27.00	SON	•		Sity Sand	2.68	13.29	50.26	32.26	1.15	0.36	0.00	8	불	QN N	2.07	18.16 1.75	75 2.67	0.00	30.0
28.50	47	0.43	17.61	Silty Sand	3.15	8.82	58.54	28.22	0.27	0.00	0.00	×S	Ę	₽.	-		ļ.	.	
30.00	R	0.40	17.90	Silty Sand	2.36	12,99	47.05	32.44	4.	3.72	0.00	8	H Z	ď	 	· .	•	ļ.	
]			1	-	-	-		0 2	₩ = 1 1 1 1 1 1 1 1 1 1
												1	1	-	-	-	\dashv		CONSULTING

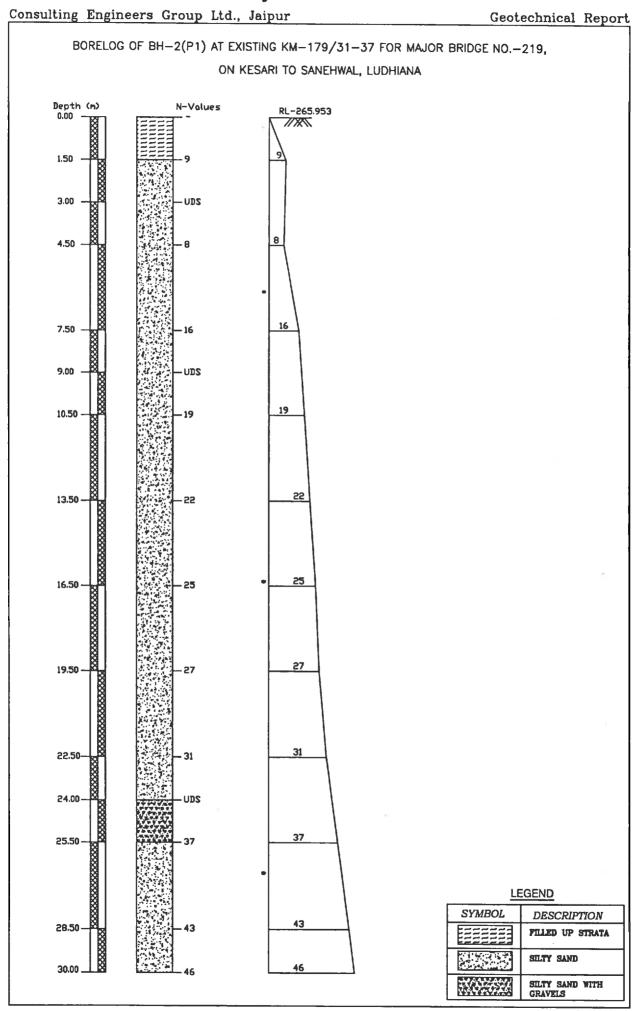
Physical Parish Physical P										_											
Cheen	Project .	Cha	inage 179/31-	-37	Date of Testing	Loca	tition at	.00	H. No.	Dec	ith of Wate	er Table	Ten	mination	Depth		\$	Surfa	ce Elevatic	_	
Conceive		8	idge No. 219	6	23.12,2009 to 24.12,2009		٤		~		07.00 n	j .		30.00ml							
Mail	Depth	Observ-	Correction	!	Soil		F	ain Size D	istribution	% wt retai	peu		Athe	rberg Lim	its %	B.D.	M.C.	D.D.	Specific	Shear Stre	mgth
N N C C N N (Seli Group)	mouj.	8	Factor		Description	į	ě		Sand		9	iravel							Gravity		•
1.44 12.56 12.46 12.56 12.46 12.56	GL (m)	z	ບໍ	Nn	(Soil Group)	à c	5	E I	Medium	-	<u> </u>	-	<u> </u>	P.L	P.I.	ээ/шб	%	ээ/шб		kg/cm²	degree
1,14 1,256 Saby Sand 3,15 7,29 63,20 61,20 0.05	0.00				Filled up Strata	٠		•		,	·		·					,			
4.005 4.64 6.45 1.02 6.72 <t< td=""><td>1.50</td><td>6</td><td>1.44</td><td>12.96</td><td>Silty Sand</td><td>3.15</td><td>7.92</td><td>59.90</td><td>28.03</td><td>0.39</td><td>0.61</td><td>0.00</td><td>8</td><td>Ä</td><td>ď.</td><td>•</td><td></td><td></td><td></td><td></td><td> .</td></t<>	1.50	6	1.44	12.96	Silty Sand	3.15	7.92	59.90	28.03	0.39	0.61	0.00	8	Ä	ď.	•					.
6 1,07 8.56 Selfy Sand 285 8,40 4,028 1,029 1,0	3.00	San	•		Silty Sand	3.68	10.88	32.29	51.28	0.78	1.09	0.00	56	쀨	Ā	1.79	1211	1.60	2.70	0.00	28.0
16 0.80 14.40 Sally Sand 3.96 11.24 4.743 36.37 0.33 1.65 0.00 25 NL NP - </td <td>4.50</td> <td>80</td> <td>1.07</td> <td>8.56</td> <td>Silty Sand</td> <td>2.85</td> <td>9.40</td> <td>45.62</td> <td>40.26</td> <td>0.65</td> <td>쳞</td> <td>900</td> <td>2</td> <td>릴</td> <td>ď</td> <td></td> <td></td> <td>·</td> <td></td> <td></td> <td></td>	4.50	80	1.07	8.56	Silty Sand	2.85	9.40	45.62	40.26	0.65	쳞	900	2	릴	ď			·			
UDS Silly Sand 0.00 3.11 6.58 6.09 4.59 0.00 4.59 0.00 4.59 0.00 2.9 NIL NP 1.51 1.765 1.52 2.70 22 0.70 16.20 0.70 0.00 2.5 NIL NP <td>7.50</td> <td>16</td> <td>08'0</td> <td>14.40</td> <td>Silty Sand</td> <td>3.98</td> <td>10.24</td> <td>47.43</td> <td>36.37</td> <td>0.33</td> <td>1.65</td> <td>0.00</td> <td>ĸ</td> <td>킬</td> <td>₫.</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	7.50	16	08'0	14.40	Silty Sand	3.98	10.24	47.43	36.37	0.33	1.65	0.00	ĸ	킬	₫.						
19 0.78 14.82 Sally Sand 4.57 4.57 0.07 0.07 25 NL NP 7 8 7 8 7 8 7 8 7 9 9 9 9 9 9 0.00 0.00 0.00 8 NL NP 9 <td>9.00</td> <td>SON</td> <td></td> <td></td> <td>Silly Sand</td> <td>000</td> <td>3,11</td> <td>85.85</td> <td>6.09</td> <td>00.00</td> <td>4.95</td> <td>000</td> <td>83</td> <td>볼</td> <td>ď</td> <td>1.91</td> <td>17.85</td> <td>1.62</td> <td>2.70</td> <td>0.00</td> <td>88</td>	9.00	SON			Silly Sand	000	3,11	85.85	6.09	00.00	4.95	000	83	볼	ď	1.91	17.85	1.62	2.70	0.00	88
27 0.70 15.20 Silly Sand 4.69 10.06 10.02 24.16 0.20 0.00 0.00 0.00 0.00 0.00 0.00 0.0	10.50	19	. 0.78	14.82	Silty Sand	3.26	7.85	43.06	45.76	0.07	0.00	0.00	ĸ	를	ě			·			
255 0.653 15.36 Sility Sand 3.84 10.66 61.02 24.16 0.20 0.00 0.00 25 NL NP ·	13.50	83	0.70	15.20	Sifty Sand	4.69	39.82	53.91	0.88	0.24	0.46	000	31	Z Z	₽.		,				
27 0.57 15.20 Silly Sand 3.26 11.52 51.32 0.540 0.00 25 NIL NP -	16.50	10	978	15.38	Silty Sand	3.84	10.66	51.02	24.16	0.32	0.00	000	82	NE	ď	•	٠	٠			
31 0.52 15.56 Silly Sand 3.75 7.57 96.21 0.70 1.24 0.00 25 NL NP <	19.50	27	0.57	15.20	Sility Sand	3.26	11.52	51.32	33.50	0.40	0.00	000	25	NE	Z d				٠		
UDS - Sity Sand with Gravels 3.85 53.05 23.01 0.35 7.86 5.90 29 NIL NP 1.54 20.40 1.61 2.89 37 0.48 16.38 Silly Sand 3.14 6.10 55.96 0.45 0.00 24 NIL NP -	22.50	31	0.52	15.56	Silty Sand	3.75	7.57	56.21	30.53	0.70	1.24	000	52	NE	ΔN				٠		
37 0.46 16.38 Silly Sand 3.14 6.10 55.86 34.55 0.09 0.14 0.00 24 NIL NP - 6 7 7 7 10 50.47 33.78 0.29 4.21 0.00 26 NIL NP - 7 7 7 7 7 10 50.47 33.78 0.29 4.21 0.00 28 NIL NP - 7 7 7 7 7 10 50.47 33.78 0.29 4.21 0.00 28 NIL NP - 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	24.00	Sdn			Silty Sand with Gravels	3.85	5.85	53.36	23.01	0.35	7.68	5.90	8	N.	Q.	<u>4</u>	20.40	1.61	2.89	0.00	28.5
43 0.44 16.96 Silly Sand 3.75 8.84 34.61 1.80 2.20 0.00 26 NIL NP · · · · · · · · · · · · · · · · · ·	25.50	37	0.48	16.38	Silty Sand	3.14	6.10	55.98	34.55	0.09	0.14	000	24	N.	₽.		,	٠			
46 0.42 17.16 Salty Sand 4.16 7.10 50.47 33.78 0.28 4.21 0.00 28 NIL NP	28.50	23	0.44	16.96	Silly Sand	3.75	979	34.61	49.00	1.60	2.20	000	82	NF	N P		١.	•			
Engineery Group Lt. 1 N C O N S ULT 1 N C O N C	30.00	46	0.42	17.16	Silty Sand	4.16	7.10	50.47	33.78	0.28	4.21	0.00	58	N	ď	,		·		,	
																			956	Engineers	Group Lad

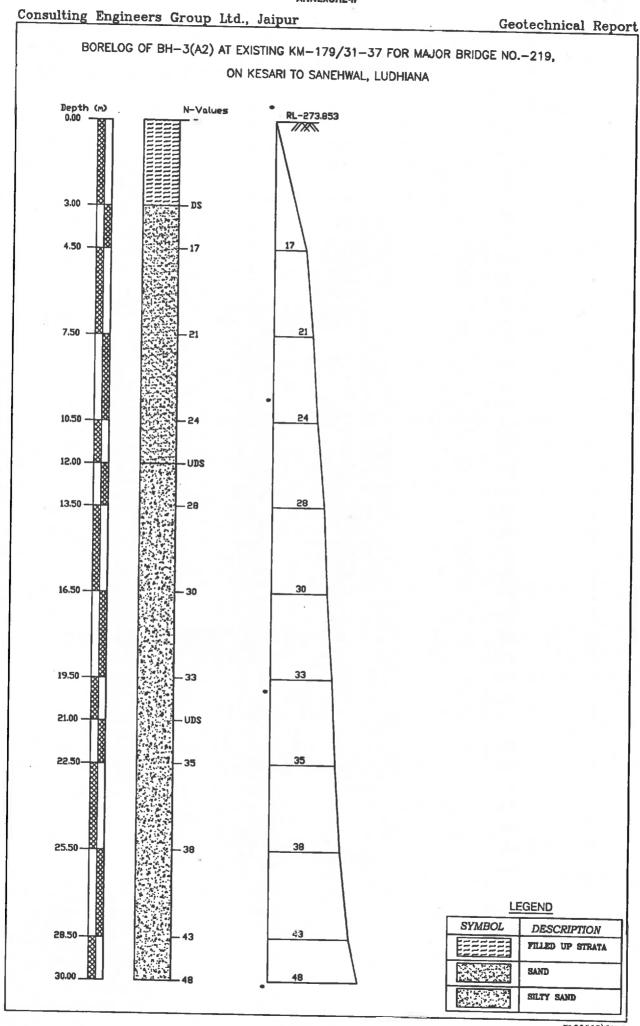
Geotechnical Report

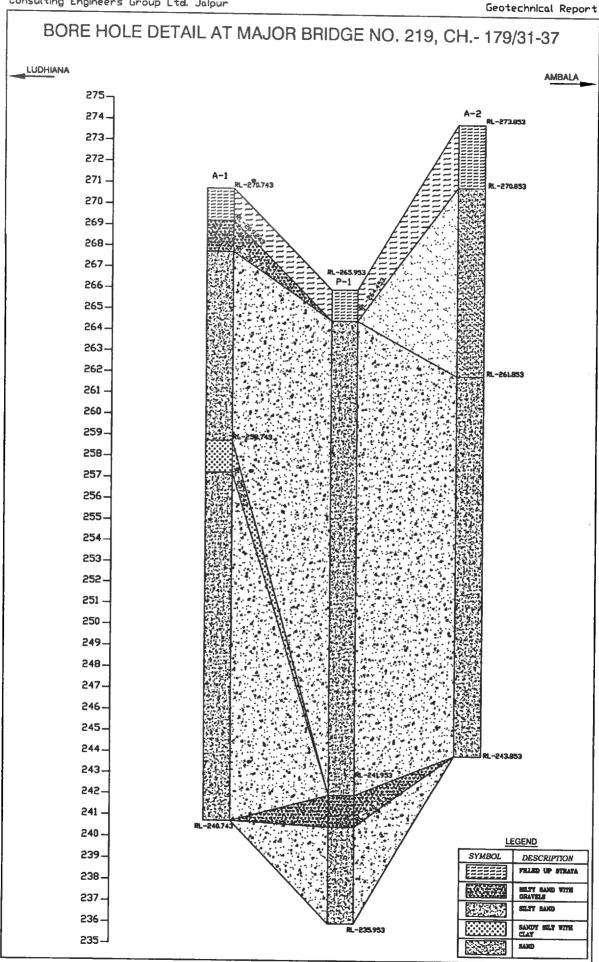
				F	•	8					T .	29.0			Ι.	28.0		T .			N N
				Shear Strength	-	cm² degree	├-	-	-	-	-	├	-	_	_	_	_	-	_	_	CONSULTING Engineers Group Lid
		ration			i	c kg/cm²	Ľ	<u> </u>	ļ.	ļ.	<u> </u>	0.0	<u> </u>	ļ. -	<u>'</u>	0.00	Ŀ	<u> </u>	ļ.	·	0 m
31-37		Surtace Elevation		Specific	Gravity	L	Ľ	Ľ	'			2.65	ŀ		٠	2.67			<u> </u> •		
179/		Sur		D.D.	-	ээ/шб			·	Ŀ	<u> · </u>	5.	·	·	·	1.61	Ŀ	·		·	
AGE				N.		8	·		Ŀ	·	Ŀ	13.01		·		15.36		<u> </u>			
CHAINAGE 179/31-37		<u> </u>		B.D.		gm/cc	·	·	·	·	·	28.	Ŀ		٠	1.86		•		·	
TCF	_	Depth	4	nits %		ā		鱼	₽	Ž	Š	ē	ě	ď.	₽.	₽	ě	Q.	₽	₹	
A 61		Termination Depth	30.00mtr	Atterberg Limits		P. P.	·	ğ	¥	¥	¥	틸	Ę	불	빌	₩ H	¥	불	륄	팋	
NO. 2	-	Ten		Atte		ᆸ	<u>.</u>	82	52	52	ĸ	92	ĸ	27	28	52	27	98	27	92	
GE		Table			Gravel	Coarse		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	
BRII		Depth of Water Table	16.00 m.	,	ğ	Fine	,	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.0	8.	0.17	0.00	
JOR		Depth		wt retained		Coarse		90.0	0.00	0.00	0.00	0,00	0.00	0.15	0.11	0.36	0.21	0.17	0.12	0.37	
BORE HOLE BH-A2 FOR MAJOR BRIDGE NO. 219 AT		-Ş		bution %	Sand	Medium		67.33	90.09	65.97	83.03	4.19	40.51	28.58	27.68	26.84	28.97	47.97	33.38	43.07	
2 FO		B.H. No.	8	Grain Size Distribution %		Fine		26.65	32.14	26.44	11.06	68.23	48.28	60.54	62.00	60.84	59.25	42.41	54,49	12.10	
ВН-А		ļ		Grain		Ĭ.		2.28	3.80	3.70	2.09	23.90	8.35	6.86	6.53 6		7.36 5	-	_		
OLE		Location at	Ş	1	_						_					9.01	-	5,77	8.32	40.84	
E H		_		_	ě	<u> </u>		3.68	4.00	3.89	3.82	3.68	2.86	3.78	3.68	2.95	4.21	3.68	3.52	3.62	
SOIL CHARACTERISTICS OF BOR		Date of Testing	24.12.2009 to 25.12.2009	Soil	Description	(Soil Group)	Filled up Strata	Sand	Sand	Sand	Sand	Silty Sand	Sifty Sand	Silty Sand	Silty Sand	Sifty Sand	Silty Sand	Silty Sand	Silty Sand	Sifty Sand	
ARACT		37		Corrected		N _n	•		18.53	19.32	19.44		20.16	17.40	17.40		17.13	17.00	17.39	18.06	
)IL CH		Chainage 179/31-37	Bridge No. 219	Correction	Factor	້ບ	٠		1.09	0.92	0.81	,	0.72	99:0	09:0	·	0.55	0.50	0.46	0.44	
SC		Chai	89	Observ-	p ₀	z		DS	17	21	24	Sau	28	30	33	SON	35	38	43	48	
		Project :		Depth	from	GL (m)	0.00	3.00	4.50	7.50	10.50	12.00	13.50	16.50	19.50	21.00	22.50	25.50	28.50	30.00	

 Θ









Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

Type	of footing	Ch 179 31-37	BH-A1	
1 2 3 4	Continuous Strip Rectangular Square Circular		Rectangular	2
Cohesi Void ra	of internal friction (¢°) ion (c in t/m2) atio (e)			26.50 0.00 0.70

S.no.	Donth (m)	
dolor of salety		3.00
Factor of safety	,	1.50
Depth of water table(m)	
Density of foundation	soil (t/m³)	1.74
Density of surcharge		1.70
	1 /	0.00
Direction of load with	vertical (")	

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:8403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d = c \; N_c \, s_c \, d_c \, i_c + q \; (N_q \cdot 1) \; s_q \, d_q \, i_q + (1/2) \; B \; \gamma \, N_r \, s_r \, d_r \, i_r \, W'$

The ultimate net bearing capacity in case of local shear failure is given by

 $q_{d}^{*} = (2/3) c N_{c}^{*} s_{c} d_{c} i_{c} + q (N_{q}^{*} - 1) s_{q} d_{q} i_{q} + (1/2) B \gamma N_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$

Where,

 $d_c = 1 + 0.2 (D_b/B) *SQRT(N_a)$

 $d_q = d_\gamma \approx 1 \text{ for } \phi < 10^\circ$

 $d_q = d_\gamma = 1 + 0.1 \; (D_l/B)^* SQRT(N_\phi) \; \; for \; \phi > \! 10^o$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

φ' for local shear failure = tan-1 (0.67 tanφ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

ф	26.50
N _c	23.55
N _q	12.98
N _y	14.34

φ,	18.47
N' _c	13.65
N' _q	5.65
N' _y	4.55

Shape factors ;

1 3.00 8.00 1.08 1.08 2 3.00 8.00 1.08 1.08	
2 0.00 0.00	0.85
	0.85
3 3.00 8.00 1.08 1.08	0.85
4 3.00 8.00 1.08 1.08	0.85

Depth factors:

S.no.	Depth(m)	Width(m)		dç	d _o	d.
1	1.50	3.00	_	1.16	. 1.08	1.08
2	3.00	3.00	•	1.32	1.16	1.16
3	4.50	3.00		1.48	1.24	1.24
4	6.00	3.00		1.65	1.32	1.32

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_0 = (1-\alpha/90)^2$	$i_v = (1 - \alpha/\phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z"/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	29.40	11.00	15.60
2	3.00	3.00	8.00	31.59	11.82	16.77
3	4.50	3.00	8.00	33.79	12.64	17.93
4	6.00	3.00	8.00	35.99	13.47	19.10

Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

Туре с	of footing	Ch 179 31-37	BH-A2	
1	Continuous Strip			
2	Rectangular		Rectangular	
3	Square		ricolangular	2
4	Circular			
		•		
	of internal friction (φ°)			26.00
Cohesi	ion (c in t/m2)			26.00
Void ra				0.00
	• •			0.75
	on of load with vertical (°)			0.00
	of surcharge (t/m³)			1.70
Density	of foundation soil (1/m3)			
	of motor tobleton			1.70

S.no.	Depth (m)	Width (m)	Length (m)
1	3.00	3.00	8.00
2	4.50	3.00	8.00
3	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Depth of water table(m)

Factor of safety

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d = c \; N_c \, s_c \, d_c \, i_c + q \; (N_q - 1) \; s_q \, d_q \, i_q + (1/2) \; B \; \gamma \, N_\gamma s_\gamma d_\gamma i_\gamma W'$

The ultimate net bearing capacity in case of local shear failure is given by $q_d' = (2/3) \ c \ N_c' s_c \ d_c \ i_c + q \ (N_q'-1) \ s_q \ d_q \ i_q + (1/2) \ B \ \gamma \ N_\gamma' s_\gamma \ d_\gamma \ i_\gamma W'$

Where,

dc = 1+ 0.2 (D/8)*SQRT(Na)

 $d_q = d_{\gamma} = 1$ for $\phi < 10^{\circ}$

 $d_q = d_\gamma = 1 + 0.1 (D_r/B)^*SQRT(N_\phi)$ for $\phi > 10^\circ$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

 ϕ' for local shear failure = tan⁻¹ (0.67 tan ϕ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

CONSULTING Engineera Group Ltd.

1.50

3.00

Jacob Bank

Bearing capacity factors :

ф	26.00
N _c	22.60
N _q	12.21
N _y	13.18

	φ'	18.10
	N'c	13.36
	N' _q	5.46
į	N',	4.35

Shape factors:

S.no.	Width(m)	Length (m)	Se	S_q	S,
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
			•		

Depth factors:

1 3.00 3.00 1.32 1.16 1.16 2 4.50 3.00 1.48 1.24 1.24	,	d _r	d _q	dc	Width(m)	Depth(m)	S.no.
2 4.50 3.00 1.48 1.24 1.24	6	1.16	1.16	1.32	3.00	3.00	1
	4	1.24	1.24	1.48	3.00	4.50	2
3 6.00 3.00 1.64 1.32 1.32	2	1.32	1.32	1.64	3.00	6.00	3

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1-\alpha/90)^{2}$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	W'
			15	
1	3.00	3.00	-0.50	0.50
2	4.50	3.00	-1.00	0.50
3	6.00	3.00	-1.50	0.50

Sale Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²) General shea	Local shear	Actual
1	3.00	3.00	8.00	29.29	11.28	11.28
2	4.50	3.00	8.00	31.31	12.06	12.06
3	6.00	3.00	8.00	33.33	12.84	12.84

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ANNEXURE - IV

Se	ttlement Calculatio	n As per IS 8009 (Part 1)
Location	Major Bridge	
Chainage	179/31-37	
Bore Hole No.	A2	

Footing Depth (m)	1.50
CDC (11 c)	
SBC (t/m2)	15.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	27.00
Depth Correction	0.01
Rigidity factor	0.91
Corrected Settlement (mm)	19.7

Ö

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	28.80
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	19.1

Footing Depth (m)	4.50
SBC (t/m2)	18.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	32.40
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	18.9

Footing Depth (m)	6.00
SBC (t/m2)	19.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	34.20
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	18.6

ANNEXURE - IV

Se	Settlement Calculation As per IS 8009 (Part 1)					
Location	Major Bridge					
Chainage	179/31-37					
Bore Hole No.	A2					

Footing Depth (m)	3.00
SBC (t/m2)	11.00
Average N value	18.00
Settlement for 10 t/m2 (mm)	17.00
Total Settlement (mm)	18.70
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	12.4

Footing Depth (m)	4.50
SBC (t/m2)	12.00
Average N value	19.00
Settlement for 10 t/m2 (mm)	16.00
Total Settlement (mm)	19.20
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	11.2

Footing Depth (m)	6.00
SBC (t/m2)	12.50
Average N value	19.00
Settlement for 10 t/m2 (mm)	16.00
Total Settlement (mm)	20.00
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	10.9



CHAPTER - 15

"Major Bridge No. 227",

Location - Existing Km. - 184/15-17



15.1 LOCATION OF STRUCTURE:

Proposed Major Bridge of Span 1 x 24.40

15.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 07.0m below EGL.

Subsurface profile at the site

Subsurrace	e profile at the site		1/4
BOREHOLE	Depth	Type of Soil/Rock	Soil/Rock
No.	(m)		Characteristics
	0.00 to 4.50	Sandy Silt with Clay	Loose
	4.50 to 10.50	Sandy Silt with Clay & Gravels	Medium Dense
BH-1(A1)	10.50 to 12.00	Silty Sand with Gravels	Medium Dense
	12.00 to 19.50	Silty Sand	Medium Dense
	19.50 to 30.00	Silty Sand	Dense
	0.00 to 3.00	Silty Sand with Gravels	Loose
	3.00 to 4.50	Sandy Silt with Gravels	Loose
	4.50 to 7.50	Sandy Silt	Medium Dense
	7.50 to 9.00	Sandy Silt with Clay	Medium Dense
BH-2(A2)	9.00 to 22.50	Silty Sand	Dense
i	22.50 to 25.50	Silty Sand	Dense
	25.50 to 28.50	Sandy Silt with Clay	Dense
	28.50 to 30.00	Silty Sand	Dense
	Below 30.00	Sandy Silt with Clay	Dense

15.3 CHEMICAL ANALYSIS OF SOIL:

BORE	BOREHOLE		CHEMICAL PROPERTIES				
No.	Depth	pН	I Carbonate Chlorides S		Sulphate	Nitrate	Salinity
	(m)			%	%	%	%
	3.00	7.60	NIL	0.0021	NIL	0.0012	0.039
BH-1 (A1)	12.00	8.60	0.005	0.0017	NIL	0.0012	0.012
	21.00	8.70	NIL	0.0022	NIL	0.0012	0.0049
	3.00	8.20	NIL	0.0017	NIL	0.0011	0.024
BH-2 (A2)	9.00	8.50	0.002	0.0014	NIL	0.0011	0.007
	24.00	7.90	NIL ·	0.0021	NIL	0.0011	0.039

15.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1(A1)	3.00	20.00

Geo-technical Investigation	Ludhiana-Ambala Section (DFCCIL)	Major Bridge No. 227
	12.00	NIL
	21.00	NIL
	3.00	NIL
BH-2 (A2)	9.00	NIL
	24.00	NIL

15.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	6.9	138	99	149	756	0.3	2.8	912	1456
Requirement as per 15:456 / Mosrth's	1 1	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	-	-

15.6 PILE LOAD CARRYING CAPACITY

15.6.1 Normal Bored Cast in- situ Pile Foundations:

Normal bored cast in situ RCC pile foundation is envisaged for the proposed bridge and have been analysed in the subsequent paragraphs. The Axial load carrying capacity of Pile in Rock is determined as per IRC-78: 2000 appendix-5.

The safe Load carrying capacities of piles have been worked out on the basis of IRC-78 as per provision/assumptions provided therein.. For calculating designed Capacity of pile recommendation of IS: 2911 should be followed. The minimum factor of safety on ultimate axial capacity should be as per clause 709.3.2 of IRC 78: 2000. The final design/construction of foundations, the safe /allowable load carrying capacity of these piles should be taken by conducting actual initial load tests on these piles casted in the respective area.

Further the piles should have necessary structural strength to transmit/sustain the design load.

Safe bearing capacity in t/m²

BH - NO.	DEPTH (mtr)	Net Allowable Bearing Pressure (t/m²)
	1.50	08.50
BH-1 (A1)	3.00	11.00
DII-I (AI)	4.50	12.00
	6.00	13.00
BH-2 (A2)	1.50	12.00
	3.00	13.50

Geo-technical Investigation	n Ludh	iana-Ambala Section (DFCCIL)	Major Bridge No. 227
	4.50	15.00	
	6.00	16.00	

Pile load carrying capacity in t

BH -NO.	PILE DEPTH	PILE CARRYING CAPACITY IN TONNE
	(mtr)	Pile Diameter= 1.20 m
	17.00	220.00
BH-1 (A1)	20.00	280.00
	23.00	350.00
	17.00	225.00
BH-2 (A2)	20.00	290.00
	23.00	360.00

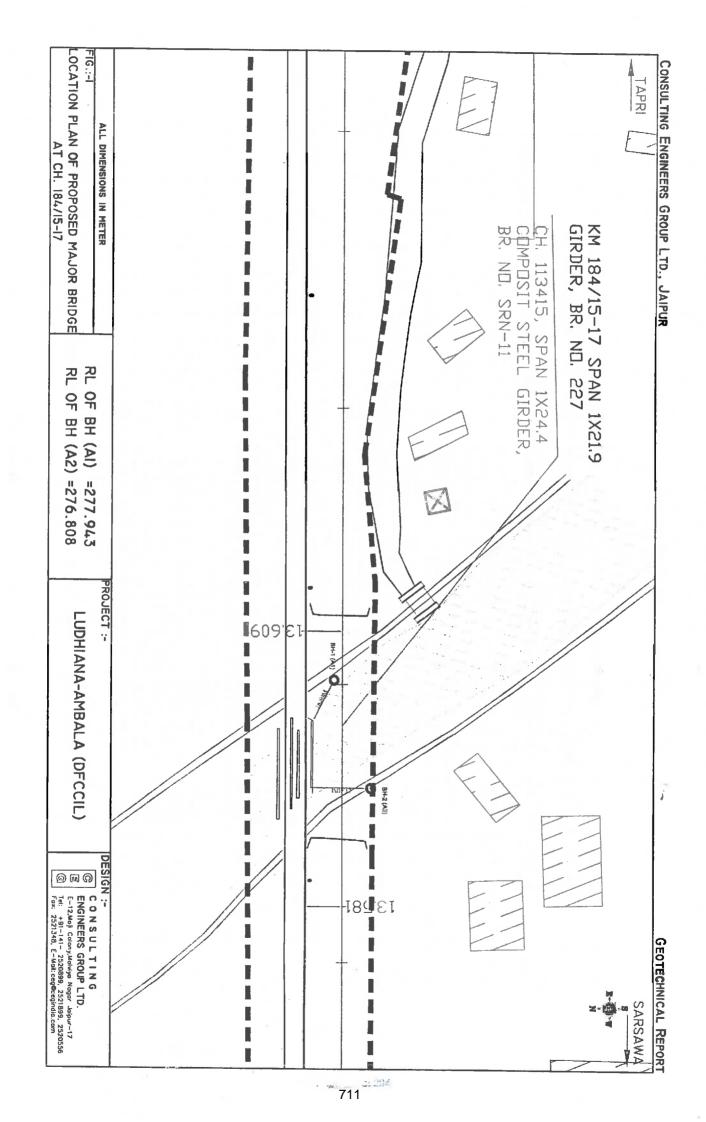
15.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

15.8 RECOMMENDATIONS

(i)	Type of foundation	Pile foundation

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



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			ength	•	degree	•		14.0		,		0.62				28.5		٠			Engineers Group Ltd.
	5		Shear Strength	2-0/-1	c ng/cm	•		0.22		,		0.00	'		•	0		-	,		C O N S Engineer
CHAINAGE 184/15-17	Surface Elevation		Specific	Gravity			,	2.62			,	2.72	-			2.7	,	-	-) PBY
/+01	Surfac		D.O.		gm/cc	·	,	1.57	٠	·		59.	·	·	٠	1.68		•	•		
			M.C.		%			17.23			•	20.00			•	19.56		•			
			B.D.		am/cc	•		18.				96:1	,			2.01	,				
	Jepth		its %		P.I.	on .	8	18	00	80	ď	Š	ď	₽.	ΝP	ΔN	ΝP	dN	ď	Ā	
	Termination Depth	30.00mtr	Atterberg Limits %		P.L.	8	8	24	21	19	킬	를	N.	ž	N.	NF	N	N	N	뢷	
	Tem		Atte		LL	83	88	42	83	27	24	8	ĸ	গ্ন	24	83	24	ន	52	82	
	r Table			Gravel	Coarse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	00:00	
	Depth of Water Table	07.00 m.	pg .	Ö	Fine	2.12	1.07	00:00	5.86	8.91	17.94	0.00	0.36	0.00	0.00	0.52	0.25	0.31	0000	0.33	
	Depth		wt retain		Coarse	0.68	0.36	0.97	0.32	1.50	1.46	0.00	0.10	0.25	0.62	0.26	0.07	0.36	0.28	0.47	
	o Z		Grain Size Distribution % wt retained	Sand	Medium	2.16	1.30	1.34	0.82	1.35	15.00	11,45	47.56	28.17	30.26	31.21	32.52	35.37	37.64	32.95	
	B.H. No.	-	Size Dist		Fine	18.67	15.04	5.40	6.76	21.18	45.43	1228	41.89	60.99	63.52	60.23	58.71	55.49	51.02	50.67	
	te		Grain	i	Ĭ	66.25	73.00	71.60	76.42	58.43	17.61	6.34	10.09	10.59	5.60	7.78	8.45	8.47	8.90	13.23	
	Location	¥1		-	à S	10.12	9.23	20.69	28.6	8.63	2.56	00:00	0.00	0.00	0.00	0.00	0.00	0.00	2.16	2.35	
	Date of Testing	21.12.2009 to 22.12.2009	Soil	Description	(Soil Group)	Sandy Silt with Clay	th Clay	Sandy Silt with Clay	Sandy Silt with Clay & Gravels	Sandy Silt with Clay & Gravels	Gravels	Silty Sand	Silty Sand	Sity Sand	Sitty Sand	Pr.	pu	Sity Sand	Sifty Sand	D	
	Date of	21.12.20091	S	Desc	Soil (Sandy Sil	Sandy Sift wi	Sandy Sil	Sandy Silt with	Sandy Silt with	Silty Sand with	Silly	Sility	Sifty	Sifty	Sifty San	Sifty Sau	Silty	Sifty	Sifty Sar	
	1		Corrected		z		12.87		13.78	15.07	15.69		16.82	16.18	16.46	•	16.94	15.96	16.53	18.37	
	Chainage 184/15-17	Bridge No. 227	Correction	Factor	ပ်ံ		54.1		90.1	0.89	0.78		0.69	0.62	0.56		0.51	0.47	0.43	0.41	
	Chain	B	Observ-	8	z		G)	san	13	17	21	san	27	28	32	san	37	36	42	53	
		- roject	Depth	mort mort	GL (m)	00.0	1.50	3.00	4.50	7.50	10.50	12.00	13.50	16.50	19.50	21.00	22.50	25.50	28.50	30.00	

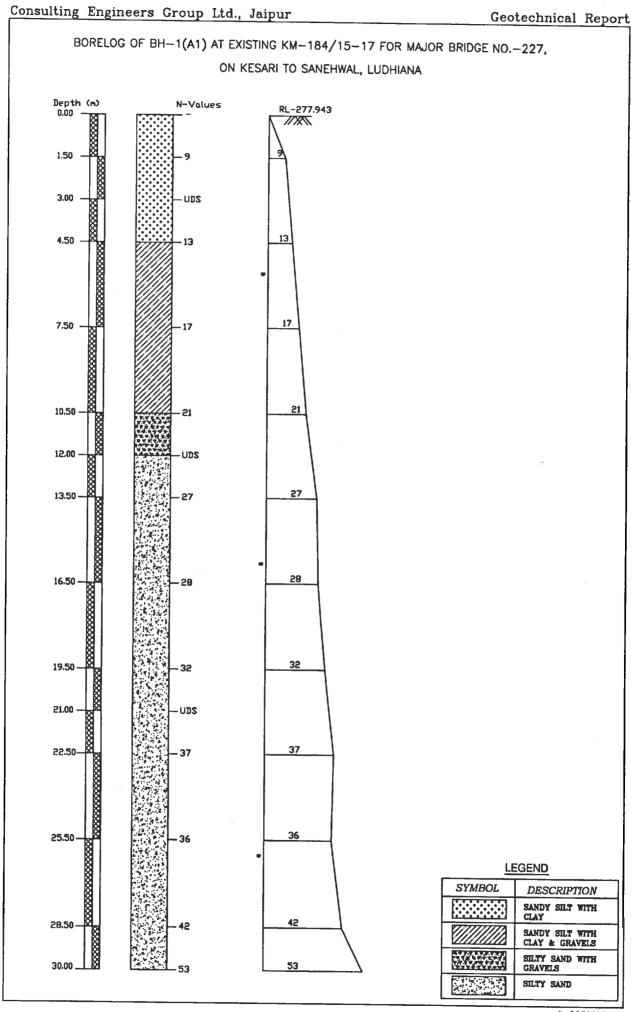
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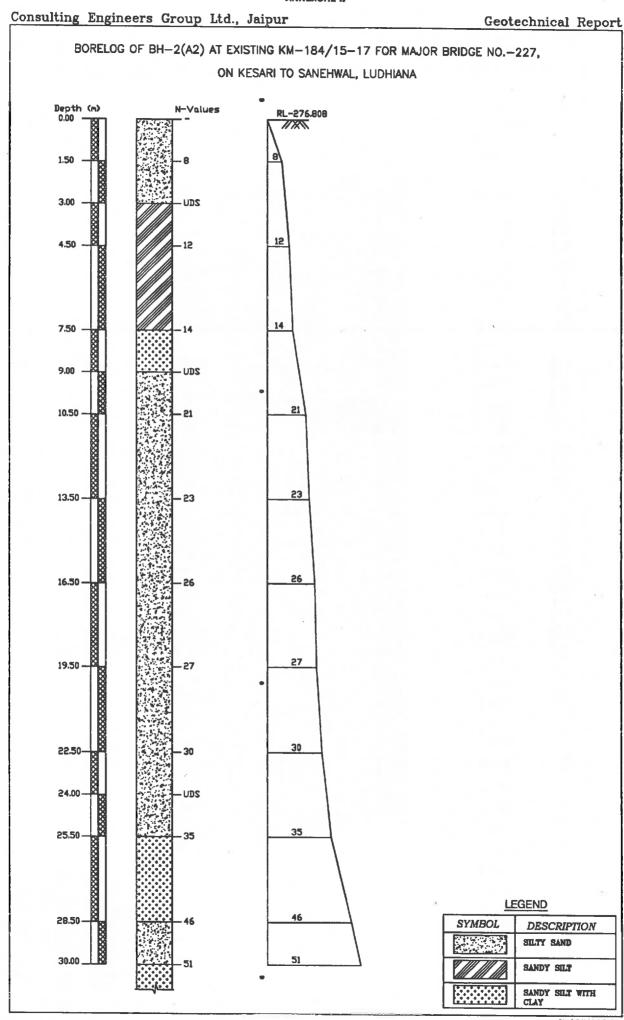
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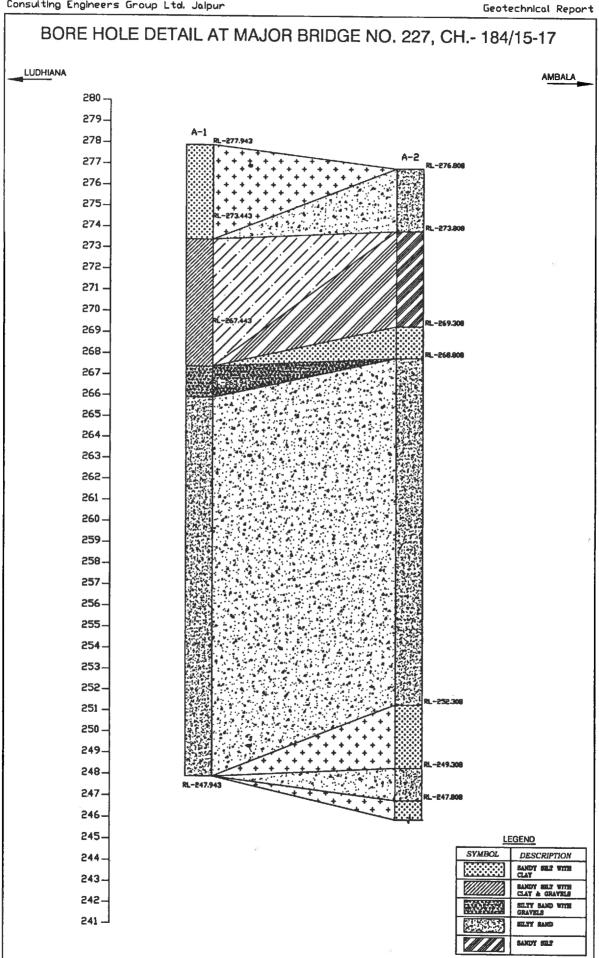
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Chance- Corrected Careele Car		Cha	inage 184/15-	.17	Date of Testing	Local	tion at	1.0	4. No.	Depth	of Water	. Table	Term	ination D.	apth			Surface	Elevation		
closed- Chosed- Chosed- Solid Acta and Control of Co	. Dec	Δ.	ridge No. 227		20.12,2009 to 21,12,2009		SI		2		07.00 m.			30.00mtr							
6 6.0 Final Protection Clay Residence plane	Depth	Observ-	Correction		Soil		Gra	in Size Di	stribution %	wt retaine	ъ		Attent	berg Limit	% si	\vdash				ar Streng	£
N C, n N, n (Spei Orcog) And sear of the control o	from	P	Factor		Description .	į	á		Sand		ő	avel				-		Ö			٠
1,145 11.40 Silly Sand with Gravele 2,69 6,046 20,42 0,24	(m)	z	ប៉	Z.	(Soil Group)	S S	<u></u>	Fine	Medium	Coarse	Fine	Coarse	, "	P.L.	\vdash	аш/сс		ээ/ш	2	dex	gree
1,150 1,15	0.00				Sifty Sand with Gravels	2.68	9.80	60.45	20.42	0.31	6.34	0.00	ĸ	N N	₽ B						
112 1.24 Silly Sand with Gravele 4.15 64.36 17.74 0.44 0.27 13.08 0.00 22 N.I. NP 1.75 13.01 1.56 112 1.28 1.28 Sandy Siltwith Clay 14.25 68.26 14.06 0.00 0.00 26 NIL NP 1.75 13.01 1.56 114 0.21 1.24 Sandy Siltwith Clay 14.42 61.46 0.00 0.00 0.00 10 1.00 0.00 26 NIL NP 1.7 1.5 1.7 1.7 1.7 1.00 0.00 0.00 0.00 1.0 1.0 1.0 0.0 0.0 0.0 0.0 1.7 1.7 1.7 1.7 1.7 0.0 0.0 0.0 0.0 0.0 1.0 1.0 0.0 0.0 0.0 0.0 1.0 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 </td <td>1.50</td> <td>60</td> <td>1.45</td> <td>11.60</td> <td></td> <td>0.00</td> <td>7.85</td> <td>60.89</td> <td>25.85</td> <td>0.29</td> <td>5.12</td> <td>0.00</td> <td>88</td> <td>Ę</td> <td>S S</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	1.50	60	1.45	11.60		0.00	7.85	60.89	25.85	0.29	5.12	0.00	88	Ę	S S						
12 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1	3.00	Sdn	·		Silty Sand with Gravels	4,15	64.58	17.47	0.44	0.27	13.09	0.00	R	ž	₽ G	1.75	13.01	<u> </u>	-	8	31.0
14 0.91 12.74 Samoy Silt with Clay 14.32 69.66 14.46 0.40 0.10 10.6 0.00 30 NIL NP 1.89 21.13 1.56 2.81 Clay 0.00 0.00 0.00 0.00 0.00 NIL NP 1.89 21.13 1.56 2.81 Clay 0.00 0.00 0.00 0.00 0.00 NIL NP 1.89 21.13 1.56 2.81 Clay 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.	4.50	2	1.08	12.96	Sandy Silt	3.65	46.35	47.00	1.00	000	0.00	0.00	82	J.	g.						
UDS 15.00 15.60 Silly Sand 3.26 11.19 61.26 0.22 6 0.24 0.00 27 NL NP 1.56 21.13 1.56 2.13 2.13 2.14 2.15 2	7.50	1	0.91	12.74		14.32	99.68	14.46	0.40	0.10	1.06	0.00	8	22	12	,	,			_	,
21 0.79 15.60 Silly Sand 4.69 30.60 0.13 0.75 0.70 0.00 27 NL NP -	9.00	SQN			Silly Sand	3.85	11.19	61.86	22.86	0.24	0.00	0.00	8	Ę	₫.		21.13		_	8	29.0
25 0.00 15.56 Sility Sand 4.19 17.29 3.37 0.00 0.00 131 NL NP - 1 - 1 - 1 - 1 - 1 1.29 1.15 1.29 2.01 2.0 1.00 2.0 NL NP - 1 - 1 - 1 - 1 - 1 1.29 1.15 1.15 1.15 1.15 1.15 1.15 1.15 1.1	10.50	2	67.0	15,80	Silty Sand	3.28	18.28	46.98	30.60	0.13	0.75	000	27	N.	<u>م</u>	,				_	٠.
256 0.633 15.68 Sility Sand 3.84 18.75 14.80 53.22 4.41 3.89 0.00 25 NL NP -	13.50	ន	0.70	15.56	Sifty Sand	4.19	21.15	71.29	3.37	00.00	0.00	000	31	NE	ď	-	- 1	,			
27 0.58 15.35 Sility Sand 3.52 11.53 29.42 48.89 2.00 24 NL NP -	16.50	ĸ	9,63	15.69	Silty Sand	3.84	19.75	14.80	53.22	4.41	3.98	000	52	NE	₽ O	•					
30 0.53 15.45 Sality Sand 3.16 4.90 49.90 35.60 2.84 3.62 0.00 26 NL NP 2.10 175 2.67 UDS -	19.50	12 .	0.58	15.33	Silty Sand	3.52	11.53	29.42	48.89	200	4.64	0.00	24	NE	<u>Q</u>						
UDS	22.50	80	0.53	15.45	Silty Sand	3.16	4.90	49.98	35.60	2.84	3.52	00:00	8	Z Z	<u>₽</u>	,		,			
35 0.46 15.90 Sandy Silf with Clay 9.54 71.44 11.05 2.69 0.99 4.29 0.00 30 22 8	24.00	SQN	,		Silty Sund	3.76	12.11	72.30	6.67	282	2.34	0.00	8	N.	ů. Z		19.56			8	29.0
46 0.44 17.62 Silty Sandy Silt with Clay 12.14 49.48 31.27 2.60 1.61 2.90 0.00 36 27 NIL NP	25.50	x	0.48	15.90		9.54	71.44	11,05	2.69	0.99	4.29	0.00	8	8	80	,		,			,
51 0.40 17.70 Sandy Silt with Clay 12.14 49.48 31.27 2.60 1.61 2.90 0.00 38 28 10	28.50	46	0.44	17.62	Silty Sand	3,26	6.77	36.83	51.50	0.73	0.91	000	27	Ę.	d Z			, .		_	
RELITORY O	30.00	51	0.40	17.70		12.14	49.48	31.27	2.60	1.61	2.90	000	8	82	10	•					
																				N S U L	T 1 X







Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 184 15-17	BH-A1	
Type	of footing			
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			
4	Circular			
Angle	of internal friction (φ°)			14.00
Cohes	ion (c in I/m2)			2.20
Void ra	atio (e)			0.68
Directi	ion of load with vertical (°)			0.00
Densit	y of surcharge (t/m³)	•		1.70
Densit	ty of foundation soil (t/m3)			1.84
Depth	of water table(m)			1.50

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Factor of safety

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\ N_c\ s_c\ d_c\ i_c+q\ (N_q-1)\ s_q\ d_q\ i_q+\{1/2\}\ B\ \gamma\ N_\gamma s_\gamma d_\gamma i_\gamma W^*$

The ultimate net bearing capacity in case of local shear failure is given by

$$q_{d}' = (2/3) \ c \ N_{c}' s_{c} \ d_{c} \ i_{c} + q \ (N_{q}'-1) \ s_{q} \ d_{q} \ i_{q} + (1/2) \ B \ \gamma \ N_{\gamma}' s_{\gamma}' d_{\gamma} i_{\gamma} W'$$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_0)$

 $d_q=d_{\gamma}=1$ for $\varphi\!<\!10^o$

 $d_q = d_\gamma = 1 + 0.1 (D/B)*SQRT(N_\phi) \text{ for } \phi > 10^\circ$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

 ϕ' for local shear failure = tan^{-1} (0.67 $tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.



3.00

Bearing capacity factors :

o	14.00	•	φ'	9.48
N _c	10.45		N'c	8.16
Nq	3.65		N' _q	2.38
N _y	2.36		N' _y	1.14

Shape factors :

S.no.	Width(m)	Length (m)	S _c	Sq	S,
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)		dc	dq	d,
1	1.50	3.00	•	1.13	1.06	1.06
2	3.00	3.00		1.26	1.13	1.13
3	4.50	3.00		1.38	1.19	1.19
4	6.00	3.00		1.51	1.26	1.26

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1-\alpha/90)^{2}$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	M.
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

General shea Local shear 1 1.50 3.00 8.00 15.42 7.99 2 3.00 3.00 8.00 16.85 8.73	Actual
2 3.00 3.00 8.00 16.85 8.73	10.59
	11.57
3 4.50 3.00 8.00 18.27 9.47	12.55
4 6.00 3.00 8.00 19.69 10.20	13.53



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 184 15-17	BH-A2	
Type o	of footing			
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			_
4	Circular		L	
Angle	of internal friction (o °)			28.00

Angle of internal friction (φ°)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.73
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m³)	1.75
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $\mathbf{q}_d = c \; N_e \, \mathbf{s}_c \, \mathbf{d}_c \, \mathbf{i}_e + \mathbf{q} \; (N_q\text{--}1) \; \mathbf{s}_q \, \mathbf{d}_q \, \mathbf{I}_q + (1/2) \; \mathbf{B} \; \gamma \, N_\gamma \mathbf{s}_\gamma \, \mathbf{d}_\gamma \, \mathbf{i}_\gamma \, \mathbf{W}^*$

The ultimate net bearing capacity in case of local shear failure is given by $q_d' = (2/3) \ c \ N_c' \ s_c \ d_c \ i_c + q \ (N_q'-1) \ s_q \ d_q \ i_q + \{1/2\} \ B \ \gamma \ N_\gamma' s_\gamma d_\gamma i_\gamma W'$

Where,

 $d_c = 1 + 0.2 (D_b/B) *SQRT(N_o)$

 $d_q = d_{\gamma} = 1 \text{ for } \phi < 10^{\circ}$

 $d_q = d_{\gamma} = 1 + 0.1 \text{ (D/B)*SQRT(N}_{\phi}) \text{ for } \phi > 10^{\circ}$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

 ϕ' for local shear failure = tan^{-1} (0.67 $tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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Bearing capacity factors:

ф	28.00	φ'	19.61
N _c	26.37	N'c	14.53
N _q	15.30	N' _q	6.21
N _y	17.79	N' _y	5.18

Shape factors:

S.no.	Width(m)	Length (m)	S _c	S _a	S.
1	. 3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors:

S.no.	Depth(m)	Width(m)		dc	d _a	d,
1	1.50	3.00		1.17	1.08	1.08
2	3.00	3.00	•	1.33	1.17	1.17
3	4.50	3.00		1.50	1.25	1.25
4	6.00	3.00		1.67	1.33	1.33

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1 - \alpha / 90)^2$	$i_{x} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	M.
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	35.48	12.39	14.70
2	3.00	3.00	8.00	38.21	13.34	15.83
3	4.50	3.00	8.00	40.93	14.30	16.96
4	6.00	3.00	8.00	43.66	15.25	18.09



Settlement Calculation As per IS 8009	· (1 att 1)					
BH No. (A1)						
Depth of foundation		=	1.5	m		
Length of footing (L)		-	8.0	m		
Width of footing (B)		=	3.0	m		
Initial effective stress at mid of layer	Po	=	6.75	t/m ²		
Concentrated load P		=	8.50			
Incerase in pressure at mid of layer	ΔΡ	=	PxIB	•		
,	1	/ _B =	_			
	ΔΡ	:=	1.9	t/m ²		
Compression Index	Cc	-	0.12	-/ 141		
Thickness of clay layer	Н	=	4.5	m		
Initial Void ratio	e _o	=	0.68			
	Po + Δp		1.0000			
	Po		1.27704	:		
Settlement of clay layer	S_f	= .	Cc 1+ co	- H	log 10	$\frac{Po + \Delta P}{Po}$
			T± GO			
			1+ 60			
	S_{f}	v	0.03414			
		-	1. 20	m		
Correction for Depth and Rigidity of fe	S_{f}	=	0.03414	m mm		
Correction for Depth and Rigidity of fo Depth Factor Calculation	S_{f}	=	0.03414	m mm		
Correction for Depth and Rigidity of for Depth Factor Calculation	S _f oundation	= = on tot	0.03414 34.1368 al settle	m mm		
Depth Factor Calculation	S_{f}	= = on tot	0.03414 34.1368 al settle	m mm		
Depth Factor Calculation	S _f oundation	= = on tot	0.03414 34.1368 al settle	m mm		
Depth Factor Calculation	S _f oundation of the D/(LB)^	= = on tot	0.03414 34.1368 al settle	m mm		
Depth Factor Calculation	S _f oundation of the D/(LB)^	= = on tot	0.03414 34.1368 al settle 0.31	m mm		
Depth Factor Calculation D = Depth of Foundation	S _f oundation of the D/(LB)^	= = on tot	0.03414 34.1368 al settle 0.31	m mm		
Correction for Depth and Rigidity of for Depth Factor Calculation D = Depth of Foundation • Depth Factor	S _f oundation of the D/(LB)^	= = on tot	0.03414 34.1368 al settle 0.31 2.67	m mm		
Depth Factor Calculation D = Depth of Foundation • Depth Factor	S _f oundation of the desired control of the	= = on tot	0.03414 34.1368 al settle 0.31 2.67	m mm ment		
Depth Factor Calculation D = Depth of Foundation Depth Factor Total	S _f D/(LB)^ L/B	= = on tot	0.03414 34.1368 al settle 0.31 2.67 0.91	m ment		-
Depth Factor Calculation D = Depth of Foundation • Depth Factor	S _f D/(LB)^ L/B	= = on tot	0.03414 34.1368 al settle 0.31 2.67 0.91	m ment		-
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Total Total Settlen	S _f D/(LB)^ L/B	= = on tot	0.03414 34.1368 al settle 0.31 2.67 0.91	m ment		-
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Total Total Settlen = 0.8	S _f D/(LB)^ L/B	= = on tot	0.03414 34.1368 al settle 0.31 2.67 0.91	m ment		-
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Total Total Settlen = 0.8 = N.A.	S _f D/(LB)^ L/B	on tot	0.03414 34.1368 al settle 0.31 2.67 0.91 digid for	mment		
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = Total Total Settlen = 0.8	S _f D/(LB)^ L/B	on tot	0.03414 34.1368 al settle 0.31 2.67 0.91	mment		

(0)



Settlement Calculation As per IS 800	9 (Part 1)
BH No. (A1)	
Depth of foundation	= 3.0 m
Length of footing (L)	= 8.0 m
Width of footing (B)	= 3.0 m
Initial effective stress at mid of layer	$Po = 9.45 t/m^2$
Concentrated load P	$= 11.00 \text{ t/m}^2$
Incerase in pressure at mid of layer	$\Delta P = P \times I_B$
	$l_{\rm B} = 0.22$
	$\Delta P = 2.4 \text{ t/m}^2$
Compression Index	Cc = 0.12
Thickness of clay layer	H = 4.5 m
Initial Void ratio	$e_0 = 0.68$
•	$\frac{Po + \Delta p}{Po} = 1.25608$
Settlement of clay layer	$S_f = \frac{Cc}{1 + eo} H \qquad \log_{10} \frac{Po + \Delta P}{Po}$
	$S_f = 0.03183 \text{ m}$
	5 ₁ - 0.05165 III
	= 31.8275 mm
Correction for Depth and Rigidity of I	toundation on total settlement
Depth Factor Calculation	
	$D/(LB)^{0.5} = 0.61$
D = Depth of Foundation	
	I /P = - 0.47
	L/B = 2.67
Depth Factor	= 0.83
•	1
	al Settlement of Rigid foundation
Rigidity Factor = Total Settler	ment at the centre of Flexible foundation
= 0.8	
= N.A.	
Total Settlement	$= S_f \times D.F. \times R.F.$
	$S_{02} = 21.1 \text{ mm}$
	-12



Settlement Calculation As per IS 800	9 (Part 1)			-		
BH No. (A1)						
Depth of foundation		=	4.5	m		
Length of footing (L)		=	8.0			
Width of footing (B)		=	3.0			
Initial effective stress at mid of layer	Po		12.15			
Concentrated load P	10		12.00			
Incerase in pressure at mid of layer	ΔΡ		P x I B			
pressure at first of layer			0.22	3		
		-		2		
Compression Index	ΔP Cc	=	2.6	t/m		
Thickness of clay layer	Н		0.1 2 4.5			
Initial Void ratio			0.68	m		
Miller Ville Idello	e _o		0.00			
	Po + Δp		1.21728	3		1
Settlement of clay layer	S_f	=.	Cc 1+ eo	- н	log 10	$\frac{Po + \Delta P}{Po}$
			1.00			10
	Sf	_	0.02745			
	Jf.	_	0.02/43	m		
			27.4474			
Correction for Depth and Rigidity of for Depth Factor Calculation	oundation	on tot	al settle	ement		
	D/(LB)^	0.5	0.92			
D = Depth of Foundation	/ (/					
D - Depth of Foundation						
	L/B	=	2.67			
Depth Factor		=	0.73			
Tota	l Settlemen	t of R	ligid for	undation		
Rigidity Factor = Total Settler						-
= 0.8						
= N.A.						
Total Settlement		=	Sex D	F.x R.F.		
	S_{t2}	=	-	mm		
	212		10.0	MILL		



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Settlement Calculation As per IS 800	9 (Part 1)					
BH No. (A1)						
Depth of foundation		=	6.0	m		
Length of footing (L)		=	8.0	m		
Width of footing (B)		-				
Initial effective stress at mid of layer	Po	=	14.85			
Concentrated load P		=		•		
Incerase in pressure at mid of layer	ΔΡ	=	PxIB	•		
		I B =	_			
	ΔΡ	140	2.9	t/m ²		
Compression Index	Cc	=		.,		
Thickness of clay layer	Н	=	4.5	m		
Initial Void ratio	eo	=				
	$\frac{\text{Po} + \Delta_1}{\text{Po}}$	=	1.19259			
Settlement of clay layer	S_f	= -	Cc 1+ eo	- Н	log 10	$\frac{Po + \Delta P}{Po}$
	S_{f}	=	0.02459	m		
Correction for Depth and Rigidity of fo Depth Factor Calculation	oundation		24.5867 al settle			
1	(LB)^0.5	/D =	0.82			
D = Depth of Foundation						
•	L/B	=	2.67			
Depth Factor		=	0.68			
Total	Settleme	nt of R	igid fou	ndation		
Rigidity Factor = Total Settlen	nent at th	e centr	e of Flex	ible fou	ndation	-
= 0.8						
= N.A.						
Total Settlement		=	S _f x D.F	x R.F.		
	S_{f2}		13.4			
	12					



Se	Settlement Calculation As per IS 8009 (Part 1)					
Location	Major Bridge					
Chainage	184/15-17					
Bore Hole No.	A2					

Footing Depth (m)	1.50
SBC (t/m2)	12.00
Average N value	12.00
Settlement for 10 t/m2 (mm)	27.00
Total Settlement (mm)	32.40
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	23.6

Footing Depth (m)	3.00
SBC (t/m2)	13.50
Average N value	13.00
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	32.40
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	21.5

Footing Depth (m)	4.50
SBC (t/m2)	15.00
Average N value	13.00
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	36.00
Depth Correction	0.74
Rigidity factor	0.8-
Corrected Settlement (mm)	21.3

Q.

Footing Depth (m)	6.00
SBC (t/m2)	16.00
Average N value	13.00
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	38.40
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	20.9

CHAPTER - 14

"Minor Bridge No. 211",

Location - Existing Km. - 172/900-173/000



14.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x 6x4

14.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 6.50m below EGL.

Subsurface profile at the site

- Jacouriae	profite at the bite		
BOREHOLE	Depth	Type of Soil/Rock	Soil/Rock
No.	(m)		Characteristics
BH-1	0.00 to 4.50	Silty Sand	Loose
D11-1	4.50 to 12.00 •	Silty Sand	Medium Dense

14.3 CHEMICAL ANALYSIS OF SOIL:

BORI	EHOLE		CI	HEMICAL I	PROPERTII	ES	
No.	Depth (m)	pН	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.60	0.005	0.0014	NIL	0.0011	0.016
D11-1	9.00	7.90	NIL	0.0014	NIL	0.0011	0.017

14.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
DI1-1	9.00	NIL

14.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties		Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit		Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	7.1	72	139	128	689	0.4	3.8	830	1362
Requirement as per 15:456 / Month's	Not less then	2000 for CC and 500 for	400	200	3000	5 ml of 0.02 normal	25 ml of 0.02 normal		-
	6.0	RCC				NaoH	H ₂ SO ₄		

14.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	09.50
BH-1	3.00	13.00
	4.50	17.00
	6.00	19.00

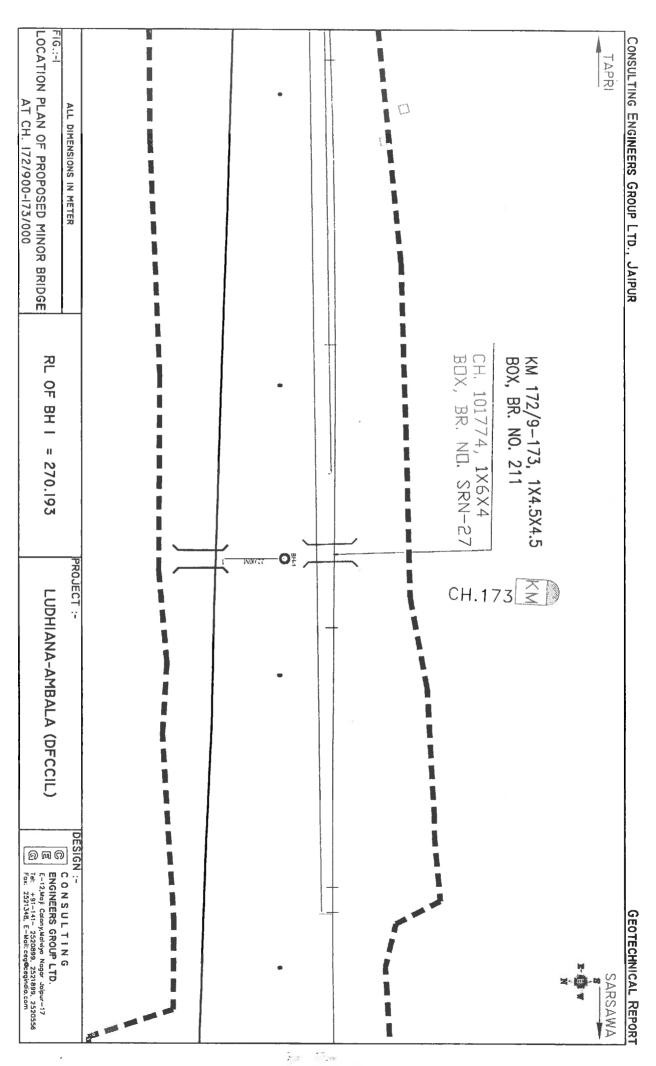
14.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

14.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation	
(ii)	Depth of foundation below GL	Below 3.00 m from EGL	

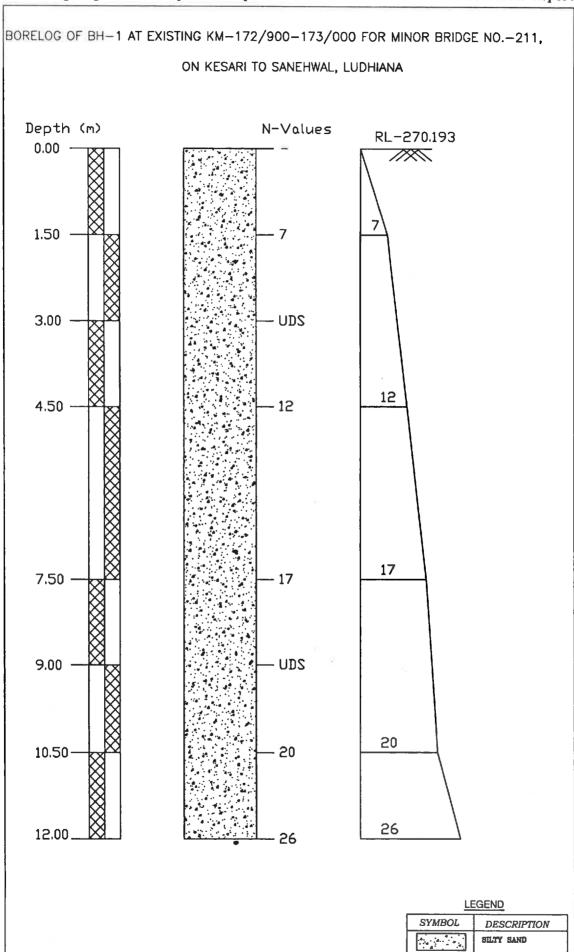
Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

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Engineers Group Lid	Engineers	OBU																		
	,		•		,	2	불	8	00.00	2.26	0.09	4.15	41.25	21.07	3.89	Silly Sand	16.99	0.73	92	12.00
				•		₫.	NF	8	0.00	0.00	0.12	32.15	40.68	23.37	3.68	Sity Sand	15.20	0.77	28	10.50
28.0	0.00	2.66	1.59	18.53	1.89	Ğ.	¥	৪	0.00	0.00	0.00	3.58	86.90	9.42	0.00	Silty Sand			san	9.00
,	,			,		ďN	H.	88	0.00	0.00	0.00	38.98	48.48	9.28	3.26	Silty Sand	15.07	0.89	17	7.50
			,	,		ď	NIL	24	0.00	0.00	0.00	5.26	51.64	39.42	3.68	Sifty Sand	12.72	1.06	51	4.50
27.0	0.00	2.68	1.55	14.77	1.78	NP.	NIC	52	0.00	0.00	0.00	1.39	86.57	6.49	3.55	Sity Sand			san	3.00
						2	¥	28	0.00	0.00	0.00	10.91	49.83	34.88	4.38	Silty Sand	10.01	1.43	7	1.50
,	ı		•			ğ	ij	8	0.00	0.00	0.00	12.64	50.36	33.32	3.68	Silty Sand			,	0.00
degree	c kg/cm²		gm/cc	36	дш/сс	P.I.	P.f.	긤	Coarse	Fine	Coarse	Medium	Fine	ž	2	(Sail Group)	ž	င်္	z	GL (m)
ŀ		Gravity							Gravel	3		Sand		ı	į	Description		Factor	P	from
rength	Shear Strength	Specific	D.D.	M.C.	B.D.	% si	Atterberg Limits %	Atte		2	w retaine	Grain Size Distribution % wt retained	in Size Dis	20		Soil	Corrected	Correction	Observ-	Depth
							12.00mtr		-	07.00 m.		_		_		30.12.2009 to 30.12.2009		Bridge No. 211		
	tion	Surface Elevation	Sur		L	Septh	Termination Depth	Tem	ar Table	Depth of Water Table	Depth	B.H. No.	B.H	Location at	Loca	Date of Testing	3/000	Chainage 172/900-173/000	Chaina	Project :
			-	-				-											_	



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

Туре с	of footing	Ch 172 900-173 000		BH-1
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			
4	Circular			

Angle of internal friction (\$\phi^{\alpha}\$)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.73
Direction of load with vertical (°)	0.00
Density of surcharge (Vm³)	1.70
Density of foundation soil (t/m³)	1.78
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	6.00	. 8.00
2	3.00	6.00	8.00
3	4.50	6.00	8.00
4	6.00	6.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d = c \; N_c \, s_c \, d_c \, i_c + q \; (N_q\text{--}1) \; s_q \, d_q \, i_q + (1/2) \; B \; \gamma \, N_r s_r d_r i_r W^*$

The ultimate net bearing capacity in case of local shear failure is given by $q'_d=(2/3)~c~N'_c\,s_c\,d_c\,l_c+q~(N'_q\text{--}1)~s_q\,d_q\,i_q+(1/2)~B~\gamma N'_\gamma s_\gamma d_\gamma i_\gamma W'$

Where.

 $d_c = 1 + 0.2 (D/B)*SQRT(N_e)$

 $d_q = d_{\gamma} = 1$ for $\phi < 10^{\circ}$

 $d_q = d_\gamma = 1 + 0.1 \; (D_f/B)^* SQRT(N_\varphi) \; \; for \; \varphi > \! 10^\circ$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

 ϕ' for local shear failure = tan⁻¹ (0.67 tan ϕ)

OUTPUT

The computer aided results for shear fallure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors:

ф	27.00
N _c	24.49
N_q	13.76
N _y	15.49

φ'	18.85
N' _c	13.94
N' _q	5.83
N' _y	4.76

Shape factors:

2 6.00 8.00 1.15 1.15 0.70 3 6.00 8.00 1.15 1.15 0.70	S.no.	Width(m)	Length (m)	Sc	S,	S,
3 6.00 8.00 1.15 1.15 0.70	1	6.00	8.00	1.15	1.15	0.70
1.10	2	6.00	8.00	1.15	1.15	0.70
	3	6.00	8.00	1.15	1.15	0.70
4 6.00 8.00 1.15 1.15 0.70	4	6.00	8.00	1.15	1.15	0.70

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d _q	d,
1	1.50	6.00	1.08	1.04	1.04
2	3.00	6.00	1.16	1.08	1.08
3	4.50	6.00	1.24	1.12	1.12
4	6.00	6.00	1.33	1.16	1.16

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1 - \alpha / 90)^2$	$i_{\nu} = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor ;

S.no.	Depth(m)	Width(m)		Z , /B	W'
1	1.50	6.00		0.00	0.50
2	3.00	6.00		-0.25	0.50
3	4.50	6.00	•	-0.50	0.50
4	6.00	6.00		-0.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	6.00	8.00	23.02	8.00	9.51
2	3.00	6.00	8.00	37.41	13.43	15.83
3	4.50	6.00	8.00	52.82	19.24	22.60
4	6.00	6.00	8.00	69.24	25.43	29.81



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189.

S	ettlement Calculation As	per IS 8009 (Part 1)
Location	Minor Bridge	
Chainage	172/900-173/000	
Bore Hole No.	1	

Footing Depth (m)	1.50
SBC (t/m2)	9.50
	7.50
Average N value	13
Settlement for 10 t/m2 (mm)	30.00
Total Settlement (mm)	28.50
Depth Correction	0.9
Rigidity Factor	0.8
Corrected Settlement (mm)	20.5

Footing Depth (m)	3.00
SBC (t/m2)	13.00
Average N value	14
Settlement for 10 t/m2 (mm)	27.00
Total Settlement (mm)	35.10
Depth Correction	0.87
Rigidity Factor	0.8
Corrected Settlement (mm)	24.4

	•
Footing Depth (m)	4.50
SBC (t/m2)	17.00
Average N value	15
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	37.40
Depth Correction	0.81
Rigidity Factor	0.8
Corrected Settlement (mm)	24.2

Footing Depth (m)	6.00
SBC (t/m2)	19.00
Average N value	16
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	39.90
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	23.6

'MAJOR BRIDGES'

CHAPTER - 13

"Minor Bridge No. 214",

Location - Existing Km. - 175/500 - 600



13.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x 1.20 x 1.20

13.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 6.50m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 7.50	Silty Sand	Loose
DII-I	4.50 to 12.00	Silty Sand	Medium Dense

13.3 CHEMICAL ANALYSIS OF SOIL:

BORE	HOLE		CI	HEMICAL I	PROPERTII	ES	
No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity
	(m)			0/0	%	%	%
BH-1	3.00	8.20	NIL	0.0026	NIL	0.0011	0.044
511-1	6.00	8.30	0.007	0.0028	NIL	0.0011	0.034

13.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
D11-1	6.00	NIL

13.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties		Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	7.0	74	139	135	685	0.4	4.6	832	1309
Requirement as per 15:456 / Month's	Not less then	2000 for CC and 500 for	400	200	3000	5 ml of 0.02 normal	25 ml of 0.02 normal	-	-
	6.0	RCC				NaoH	H ₂ SO ₄		

13.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	6.00
	3.00	6.50
BH-1	4.50	9.50
	6.00	11.50

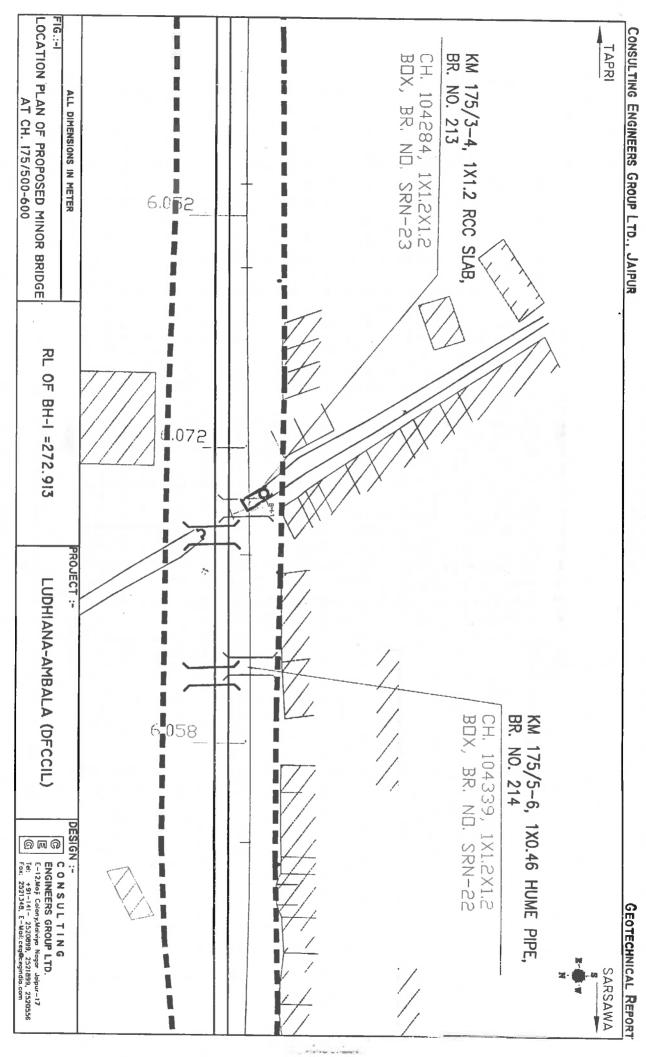
13.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

13.8 RECOMMENDATIONS

O.	KEC	OMINICIADATIONS	
Γ	(i)	Tupe of foundation	Open & Raft foundation
L	(1)		
ſ		Depth of foundation below	Below 6.00 m from EGL
1	(ii)	GI GI	Delow 0.00 III Irom 202
- 1	` '	GL	

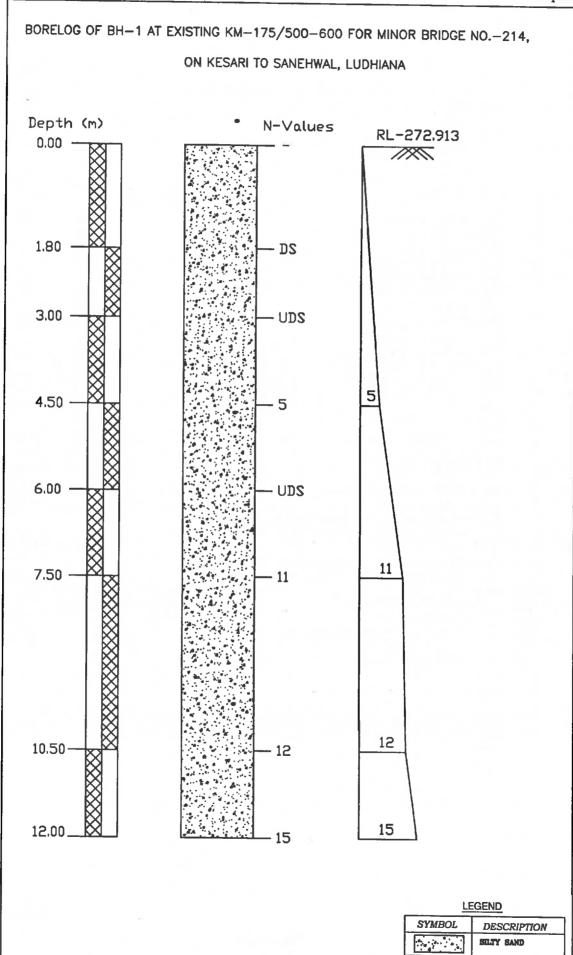
Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

	_					$\overline{}$	Т	•							0 4 15
				hgu	•	degree	'		28.0		27.5				Engineers Group Ltd.
!		5		Shear Strength	, kalom²		•		0.00	,	0:00		,		N Selection (N)
200		Surface Elevation		Specific	Gravity				2.64	•	2.65	,			
175/		Surfa		D.D.		gm/cc	,		1.55	,	1.50				
AGE				M.C.		%			8.36	•	13.39	•		,	
IAIN				B.D.		эт/сс		,	1.68	•	1.75	,			
TC		epth		ts %		P.I.	Q.	g G	Q.	P	Z	Ď	ď	Q.	
214 A		Termination Depth	12.00mtr	Atterberg Limits		P.L	J.	NF	NIC	NIL	NIL	Ę	N.	NIF	
No.		Term		Atter		7	24	25	56	23	58	30	<u>ب</u>	30	
IDGE		Table			Gravel	Coarse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
R BR		Depth of Water Table	06.50 m.	٦	S	Fine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
ONII		Depth		At retains		Coarse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
ORE HOLE AT BH-1 FOR MINOR BRIDGE No. 214 AT CHAINAGE 175/500		No.		Grain Size Distribution % wt retained	Sand	Medium	4.26	3.68	2.98	15.40	1.32	15.75	6.61	1.61	
8H-1		B.H. No.		Size Dist		Fine	80.26	77.62	78.44	70.49	83.53	71.54	58.90	85.56	
EAT		on at		Grain		is s	12.80	15.72	15.59	11.43	10.90	8.46	30.13	8.83	
HOL		Location at	-			Clay	2.68	2.98	2.99	2.68	4.25	4.25	4.36	4.00	
SOIL CHARACTERISTICS OF BORE		Date of Testing	29.12.2009 to 29.12.2009	Soil	Description	(Soil Group)	Silty Sand	e Sity Sand	Silty Sand	Silty Sand	S#ty Sand	Silty Sand	Silty Sand	Silty Sand	
RACTI				Corrected		ž				5.45		10.01	9.48	11.25	
IL CHA		Chainage 175/500	Bridge No. 214	Correction	Factor	បឹ				1.09		0.91	0.79	0.75	
1		, c	8	Obsort	2	Z		SO	Sau	25	san	=	51	15	
10.0 (10.1 (Project :	4	2	GL (m)	00.00	1.80	3.00	4.50	6.00	7.50	10.50	12.00	

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Calculation of SBC for shallow foundations as per IS: 6403 - 1981

		Ch 175 500-600		BH-1
Type o	of footing			
1	Continuous Strip			
2	Rectangular		Continuous Strip	1 1
3	Square			
4	Circular			
Angle (of internal friction (φ °)	-		28.00
Cohesi	ion (c in t/m2)			0.00
Void ra	itio (e)			0.70
Direction	on of load with vertical (°)			0.00
Density	y of surcharge (t/m³)			1.68

S.no.	Depth (m)	Width (m)	
1	1.50	1.20	
2	3.00	1.20	
3 .	4.50	1.20	
4	6.00	1.20	

SHEAR FAILURE CRITERIA

Density of foundation soil (t/m3)

Depth of water table(m)

Factor of safety

Assumptions and formula used in calculation as per IS:6403-1981 are given below

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,i_c+q\;(N_q-1)\;s_q\,d_q\,i_q+(1/2)\;B\;\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$

The ultimate net bearing capacity in case of local shear failure is given by $q'_d = (2/3) \ c \ N'_c \ s_c \ d_c \ i_c + q \ (N'_q - 1) \ s_q \ d_q \ i_q + (1/2) \ B \ \gamma \ N'_\gamma \ s_q \ d_i \ j_W'$

Where,

 $\begin{array}{l} d_c = 1 + 0.2 \; (\text{D/B})^* \text{SQRT}(\text{N}_\phi) \\ d_q = d_\gamma = 1 \; \text{for} \; \phi < \! 10^\circ \\ d_q = d_\gamma = 1 + 0.1 \; (\text{D/B})^* \text{SQRT}(\text{N}_\phi) \; \; \text{for} \; \phi > \! 10^\circ \\ \text{N}_\phi = \tan^2(\pi/4 + \! \phi/2) \\ \phi' \; \text{for local shear failure} = \tan^{-1} \left(\; 0.67 \; tan\phi \; \right) \end{array}$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.



1.68

1.50

3.00

Bearing capacity factors :

-		
	ф	28.00
	N _c	26.37
	N _q	15.30
1	N _y	17.79

φ'	19.61
N'c	14.53
N' _q	6.21
N' _y	5.18

Shape factors:

S.no.	Width(m)	Sc	S,	S,
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00
3	1.20	1.00	1.00	1.00
4	1.20	1.00	1.00	1.00

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d _q	d,
1	1.50	1.20	1.42	1.21	1.21
2	3.00	1.20	1.83	1.42	1.42
3	4.50	1.20	2.25	1.62	1.62
4	6.00	1.20	2.66	1.83	1.83

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_0 = (1 - \alpha / 90)^2$	$i_{x} = (1 - \alpha / \dot{a})^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _* /B	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50
3	4.50	1.20	-2.50	0.50
4	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m²)		
_			General shear	Local shear	Actual
1	1.50	1.20	15.22	5.28	7.76
2	3.00	1.20	17.84	6.19	9.10
3	4.50	1.20	20.47	7.10	10.44
4	6.00	1.20	23.09	8.00	11.77



S	ettlement Calculation	on As per IS 8009 (Part 1)	
Location	Minor Bridge		
Chainage	175/500-600		
Bore Hole No.	1		

Footing Depth (m)	1.50
SBC (t/m2)	6.00
Average N value	5
Settlement for 10 t/m2 (mm)	100.00
Total Settlement (mm)	60.00
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	39.8

Footing Depth (m)	3.00
SBC (t/m2)	6.50
Average N value	5
Settlement for 10 t/m2 (mm)	100.00
Total Settlement (mm)	65.00
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	38.0

Footing Depth (m)	4.50
SBC (t/m2)	9.50
Average N value	6
Settlement for 10 t/m2 (mm)	80.00
Total Settlement (mm)	76.00
Depth Correction	0.63
Rigidity Factor	0.8
Corrected Settlement (mm)	38.3

Footing Depth (m)	6.00
SBC (t/m2)	17.00
Average N value	9
Settlement for 10 t/m2 (mm)	44.00
Total Settlement (mm)	74.80
Depth Correction	0.63
Rigidity Factor	0.8
Corrected Settlement (mm)	37.7

CHAPTER - 12

"Minor Bridge No. 215",

Location - Existing Km. - 176/200 - 300



12.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x 1.20 x 1.20

12.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.00m below EGL.

Subsurface profile at the site

BOREHOLE	D. d		
1 1	Depth	Type of Soil/Rock	Soil/Rock
No.	(m)	,	
			Characteristics
[]	0.00 to 7.50	Silty Sand	Loose
BH-1	7.50 to 12.00	Silty Sand	
1 1			Medium Dense
	Below 12.00	Clayey Silt	Medium Dense

12.3 CHEMICAL ANALYSIS OF SOIL:

BORI	EHOLE		C	HEMICAL	PROPERTI	78	
No.	Depth (m)	pН	Carbonate		Sulphate	Nitrate	Salinity
BH-1	3.00	7.90	NIL	0.0017	% NIL	0.0012	0.029
	12.00	8.70	0.005	0.0021	NIL	0.0012	0.029

12.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

	TIADEX (DES)	
Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	12.00	15.00

12.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	7.2	71	126	129	683	0.5	4:8	825	1275
Requirement as per 15:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	-	-

12.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	08.50
BH-1	3.00	10.00
	4.50	11.50
	6.00	13.00

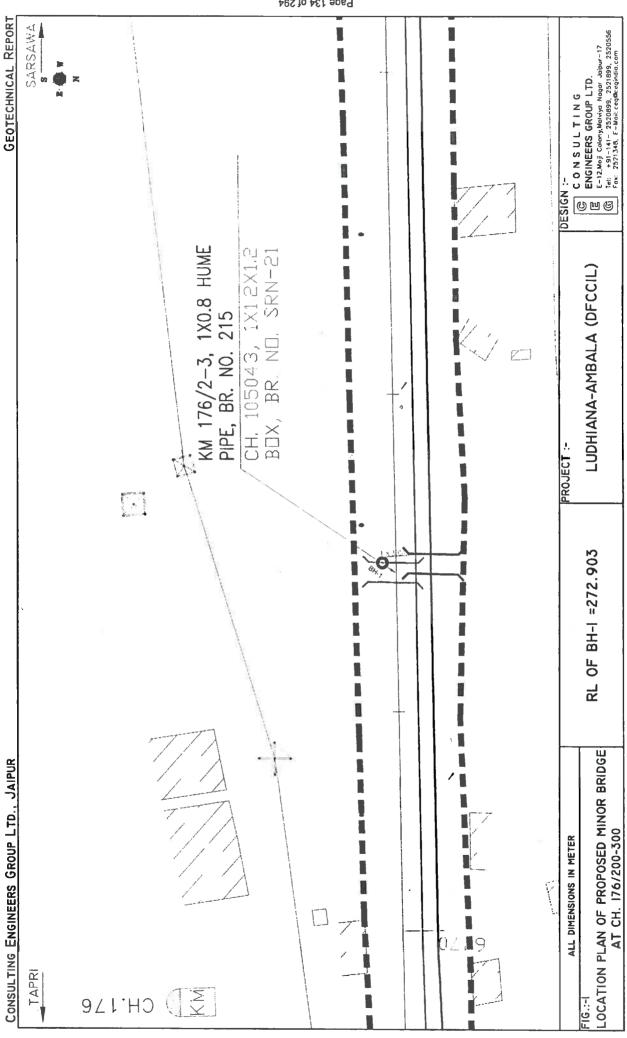
12.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

12.8 RECOMMENDATIONS

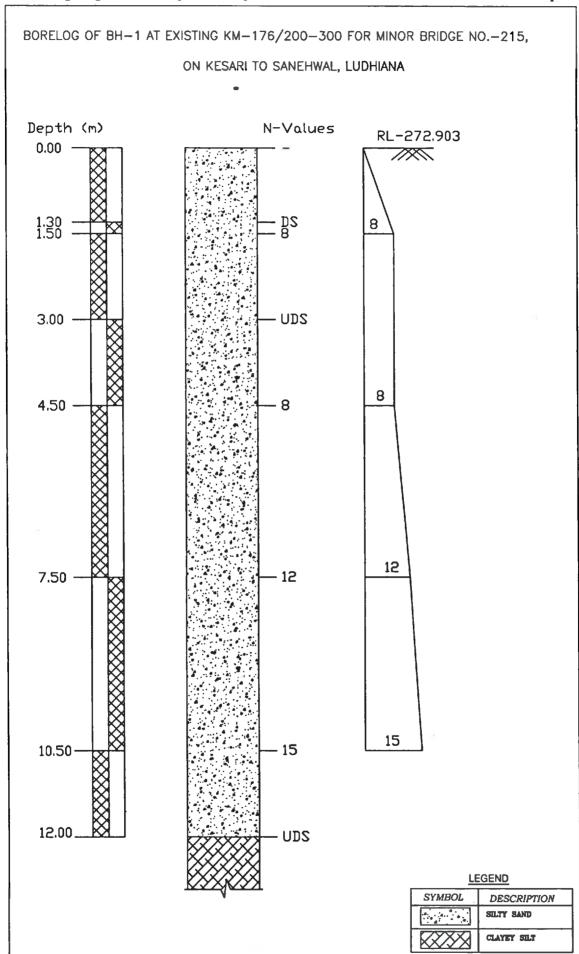
(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 6.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

		-
•		- san
11.85	0.79 11.85	15 0.79
10.80	0.90 10.80	12 0.90
100 000	1.07 8.56	1.07
		SON
	1.44	
0	c	
### Solity Sand 11.52 Silty Sand Silt		Chainage 178 Bridge No. 6 N C. Correct DS



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

Type o	of footing	Ch 176 200-300	BH-	ı
1 2 3	Continuous Strip Rectangular Square		Rectangular	2
4 Angle	Circular of internal friction (ϕ °)		L	27.50
Void ra	ion (c in t/m2) atio (e) on of load with vertical (°)			0.00 0.68 0.00

	dation soil (t/m³)	1.70 1.80	
Depth of water Factor of safety		1.50 3.00	
S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	1.20	8.00
2	3.00	1.20	8.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	1.20	8.00
2	3.00	1.20	8.00
3	4.50	1.20	8.00
4	6.00	1.20	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $\mathbf{q}_{d} = c \; N_{e} \, s_{e} \, d_{e} \, i_{e} + q \; (N_{q}\text{-}1) \; s_{q} \, d_{q} \, i_{q} + (1/2) \; B \; \gamma \, N_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W^{*}$

The ultimate net bearing capacity in case of local shear failure is given by $q'_{d} = (2/3) \; c \; N'_{c} \, s_{c} \, d_{c} \, i_{c} + q \; (N'_{q}\text{-}1) \; s_{q} \, d_{q} \, i_{q} + (1/2) \; B \; \gamma \, N'_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_0)$

 $d_q = d_y = 1$ for $\phi < 10^\circ$

 $d_q = d_\gamma = 1 + 0.1 \text{ (D/B)*SQRT(N_0)} \text{ for } \phi > 10^\circ$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

\$\phi^* \text{ for local shear failure = \text{tan}^-1 (0.67 \text{ tan} \phi)

OUTPUT

The computer aided results for snear to a criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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Bearing capacity factors :

ф	27.50
N _c	25.43
N _q	14.53
N.	16.64

φ'	19.23
N'c	14.24
N' _q	6.02
N' _Y	4.97

Shape factors:

S.no.	Width(m)	Length (m)	S _c	S,	s,
1	1.20	8.00	1.03	1.03	0.94
2	1.20	8.00	1.03	1.03	0.94
3	1.20	8.00	1.03	1.03	0.94
4	1.20	8.00	1.03	1.03	0.94

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d _q	d,
1	1.50	1.20	1.41	1.21	1.21
2	3.00	1.20	1.82	1.41	1.41
3	4.50	1.20	2.24	1.62	1.62
4	6.00	1.20	2.65	1.82	1.82

inclination factors :

$i_c = (1-\alpha/90)^2$	$i_0 = (1-\alpha/90)^2$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	 Z_w/B 	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50
3	4.50	1.20	-2.50	0.50
4	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	1.20	8.00	14.82	5.25	8.60
2	3.00	1.20	8.00	17.36	6.15	10.07
3	4.50	1.20	8.00	19.89	7.05	11.54
4	6.00	1.20	8.00	22.42	7.95	13.01



* 138 M. 274

ANNEXURE - IV

S	Settlement Calculation As per IS 8009 (Part 1)						
Location	Minor Bridge						
Chainage	176/200-300						
Bore Hole No.	1						

Footing Depth (m)	1.50
SBC (t/m2)	8.50
Average N value	10
Settlement for 10 t/m2 (mm)	36.00
Total Settlement (mm)	30.60
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	20.3

Footing Depth (m)	3.00
SBC (t/m2)	10.00
Average N value	10
Settlement for 10 t/m2 (mm)	36.00
Total Settlement (mm)	36.00
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	21.0

Footing Depth (m)	4.50
SBC (t/m2)	11.50
Average N value	9
Settlement for 10 t/m2 (mm)	44.00
Total Settlement (mm)	50.60
Depth Correction	0.62
Rigidity Factor	0.8
Corrected Settlement (mm)	25

Footing Depth (m)	6.00
SBC (t/m2)	13.00
Average N value	10
Settlement for 10 t/m2 (mm)	28.00
Total Settlement (mm)	36.40
Depth Correction	0.63
Rigidity Factor	0.8
Corrected Settlement (mm)	18.3

CHAPTER - 11

"Minor Bridge No. 216",

Location - Existing Km. - 178/02-03



11.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x2x2

11.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.00m below EGL.

Subsurface profile at the site

BOREHOLE	Depth Depth	T	
No.	(m)	Type of Soil/Rock	Soil/Rock
Dire	0.00 to 3.00	Silty Sand with Gravels	Characteristics
BH-1	3.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Loose
CHEMICA	*		Medium Dense

11.3 CHEMICAL ANALYSIS OF SOIL:

	BORI	EHOLE	JIB OF		TEN CYCL			
	No.	Depth	рН	Carbonato	HEMICAL	PROPERTI	ES	
		(m)		Carbonate	Chlorides %		Nitrate	Salinity
ı	BH-1	3.00	7.90	NIL	0.0028	%	%	%
Ĺ		6.00	7.90	NIL	0.0028	NIL	0.0012	0.088
	Dinne				0.0017	NIL	0.0011	0.029

11.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	INDEX (DFS)	
Dote Hole No.	Depth (m)	DECT
BH-1	3.00	DFS Index in %
D11-1		NIL
	6.00	NIL
CHENTE		TAIL

11.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties Test			Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit		Alkalinity (ml)		Conducti vity (µS/cm)
Result	6.7	60	128	110	712	0.3	4.6	830	1000
Requirement	1	2000 for	400	200	3000	PD 1		030	1293
asper 15:456	less	CC and		200	3000	5 ml of	25 ml of	-	2
/Morth's	then	500 for				0.02	0.02		1
	6.0	RCC				normal	normal		
						NaoH	H ₂ SO ₄		

11.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	07.00
BH-1	3.00	11.00
D11-1	4.50	13.50
	6.00	15.00

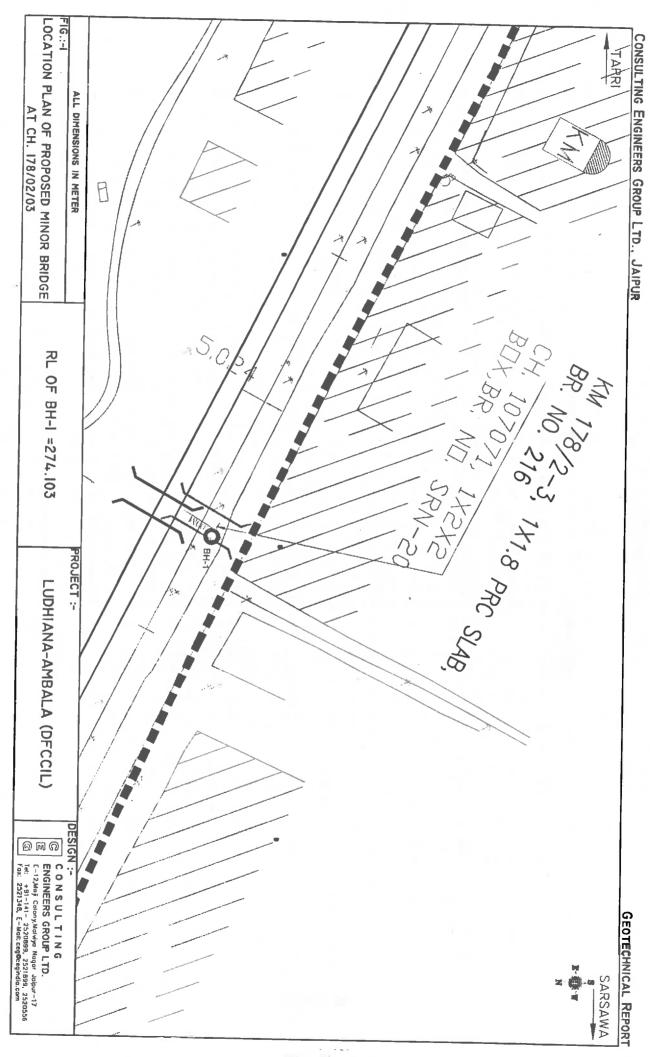
11.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

11.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

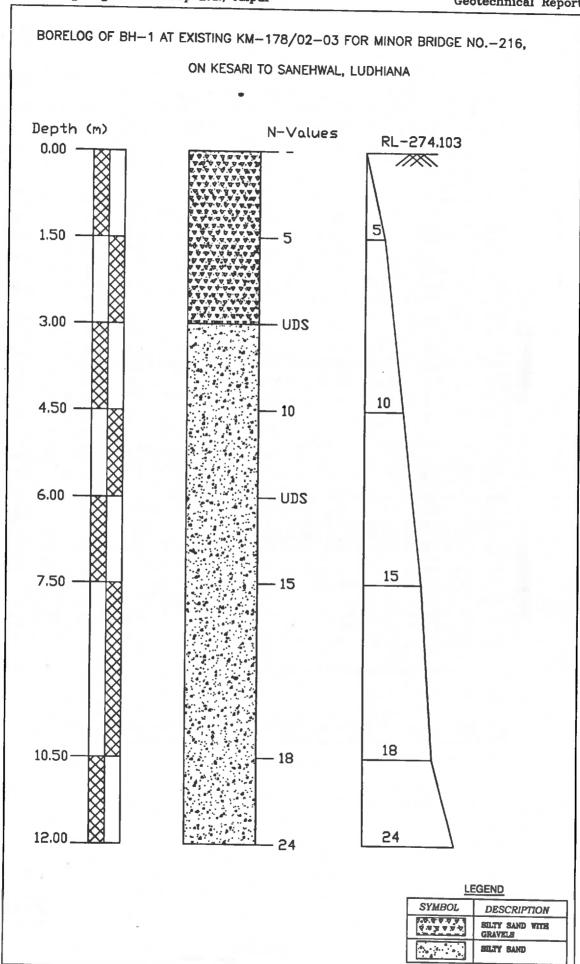
	SO	IL CHA	RACT!	SOIL CHARACTERISTICS OF BORE	HOL	ATE	H-1 F	ORE HOLE AT BH-1 FOR MINOR BRIDGE No. 217 AT CHAINAGE 178/02-03	INOR	BRII	DGE	Vo. 21	7 AT	СН	NI A	GE 1	78/0	2-03		1
	Chai	Chainage 178/02-03	-03	Date of Testing	Location at	on at	B.H.	B.H. No.	Depth o	Depth of Water Table	Table	Termir	Termination Depth	pth			Surface	Surface Elevation	S	İ
Project :	ň	Bridge No. 217		27.12.2009 to 27.12.2009	1			1		07.00 m.		-	12.00mtr							
Depth	Observ-	Correction	Corrected	Soil		Grai	n Size Dis	Grain Size Distribution % wt retained	wt retained			Alterb	Atterberg Limits %		B.D.	M.C.	D.D. S	Specific	Shear Strength	ngth
from	8	Factor		Description	ō	1:0		Sand		Gravel	vel						5	Gravity	2 kg/cm ²	•
GL (m)	z	౮	Ą	(Soil Group)	Cay	i o	Fine	Medium	Coarse	Fine	Coarse	-	P.L	P.I. g	дш/сс	%	gm/cc			degree
0.00	,			Silty Sand with Gravels	3.65	25.71	42.39	20.15	1.52	6.58	0.00	25	Ę	ů. Z	,	,				,
1.50	lo.	1.40	2.00	Silty Sand with Gravels	3.86	26.55	41.72	16.20	1.77	9.90	0.00	27	- I	Q.						
3.00	san			Silty Sand	2.85	35.10	53.50	8.55	0.00	00.00	0.00	22	- I	g.	1.70	8.50	1.56	2.67	0.00	27.0
4.50	01	ş: -	10.40	Sifty Sand	3.68	13.74	61.57	21.01	0.00	00:00	00:00	28	Į.	Q.		•				
6.00	san			Silty Sand	00:00	6.84	78.80	13.95	0.41	0.00	0.00	83	NIL NIL	Q. Ž	1.98	18.15	1.78	2.68	8:0	28.0
7.50	15	0.86	12.90	Silty Sand	0.00	6.64	78.53	14.83	0.00	0.00	0.00	53	Ę	<u>D</u>			,	,		
10.50	18	0.74	13.32	Sitty Sand	3.69	17.29	75.46	3.42	0.14	0.00	0.00	56	F F	₽.			-			
12.00	24	0.70	15.90	Silty Sand	2.86	11.43	78.01	7.50	0.10	0.10	0.00	23	HZ	<u>a</u>	٠,	-				
																		UBG	C O N S	Engineers Group Ltd.

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Calculation of SBC for shallow foundations as per IS: 6403 - 1981

		Ch 178 2-3	BH-1	
Type o	f footing		i	
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			
4	Circular	•		

Angle of internal friction (\$\displaystyle{0}\displaystyle{0}	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m³)	1.80
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	2.00	8.00
2	3.00	2.00	8.00
3	4.50	2.00	8.00
4	6.00	2.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,i_c+q\;(N_q-1)\;s_q\,d_q\,l_q+(1/2)\;B\;\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3) c N'_c s_c d_c i_c + q (N'_q-1) s_q d_q i_q + (1/2) B \gamma N'_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_{\phi})$

 $d_q = d_y = 1 \text{ for } \phi < 10^{\circ}$

 $d_q = d_\gamma = 1 + 0.1 \; (D_r/B)^* SQRT(N_\phi) \; \; \text{for} \; \phi > 10^o$

 $N_0 = \tan^2(\pi/4 + \phi/2)$

 ϕ' for local shear failure = tan⁻¹ (0.67 tan ϕ)

<u>OUTPUT</u>

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

ф	27.00
N _c	24.49
N _q	13.76
N _y	15.49

41	
φ'	18.85
N'c	13.94
N' _q	5.83
N' _y	4.76

Shape factors :

S.no.	Width(m)	Length (m)	Sc	S.	S.
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90
3	2.00	8.00	1.05	1.05	0.90
4	2.00	8.00	1.05	1.05	0.90

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d _o	d.
1	1.50	2.00	1.24	1.12	1.12
2	3.00	2.00	1.49	1.24	1.24
3	4.50	2.00	1.73	1.37	1.37
4	6.00	2.00	1.98	1.49	1.49

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1-\alpha/90)^{2}$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	W'
1	1.50	2.00	0.00	0.50
2	3.00	2.00	-0.75	0.50
3	4.50	2.00	-1.50	0.50
4	6.00	2.00	-2.25	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	2.00	8.00	21.73	7.90	11.36
2	3.00	2.00	8.00	24.10	8.76	12.59
3	4.50	2.00	8.00	26.47	9.62	13.83
4	6.00	2.00	8.00	28.84	10.48	15.07

ANNEXURE - IV

Se	Settlement Calculation As per IS 8009 (Part 1)			
Location	Minor Bridge			
Chainage	178/02-03			
Bore Hole No.	1			

Footing Depth (m)	1.50
SBC (t/m2)	7.00
Average N value	9
Settlement for 10 t/m2 (mm)	48.00
Total Settlement (mm)	33.60
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	24.5

Footing Depth (m)	3.00
SBC (t/m2)	11.00
Average N value	10
Settlement for 10 t/m2 (mm)	32.00
Total Settlement (mm)	35.20
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	23.4

Footing Depth (m)	4.50
SBC (t/m2)	13.50
(,,	
Average N value	12
Settlement for 10 t/m2 (mm)	23.00
Settlement for 10 yaiz (min)	2.7.00
Total Settlement (mm)	31.05
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	18.4

Footing Depth (m)	6.00
SBC (t/m2)	15.00
Average N value	13
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	31.50
Depth Correction	0.67
Rigidity Factor	0.8
Corrected Settlement (mm)	16.9

CHAPTER - 10

"Minor Bridge No. 217",

Location - Existing Km. - 178/30-32



10.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x 6.10

10.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.50m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
DII 1	0.00 to 4.50	Silty Sand	Loose
BH-1	4.50 to 12.00	Silty Sand	Medium Dense

10.3 CHEMICAL ANALYSIS OF SOIL:

BORE	HOLE		CI	HEMICAL I	PROPERTI	ES	
No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity
	(m)	-		%	%	%	%
DIT 1	3.00	8.60	NIL	0.0021	NIL	0.0015	0.061
BH-1	6.00	8.90	NIL	0.0025	NIL	0.0015	0.067

10.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
Dri-1	6.00	NIL

10.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	7.1	74	132	125	682	0.4	3.9	821	1312
Requirement	Not	2000 for	400	200	3000	5 ml of	25 ml of	-	-
asper IS:456	less	CC and				0.02	0.02		!
/ Morth's	then	500 for				normal	normal		[
	6.0	RCC	l			NaoH	H ₂ SO ₄		

10.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	12.00
BH-1	3.00	13.00
	4.50	14.00
	6.00	15.00

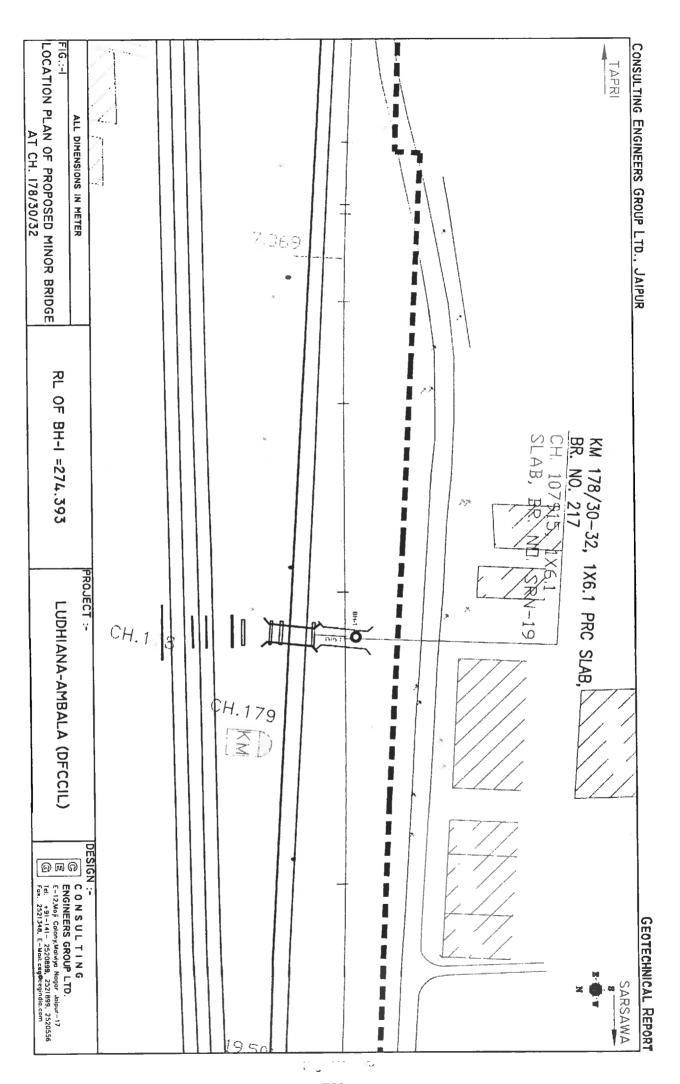
10.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

10.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.

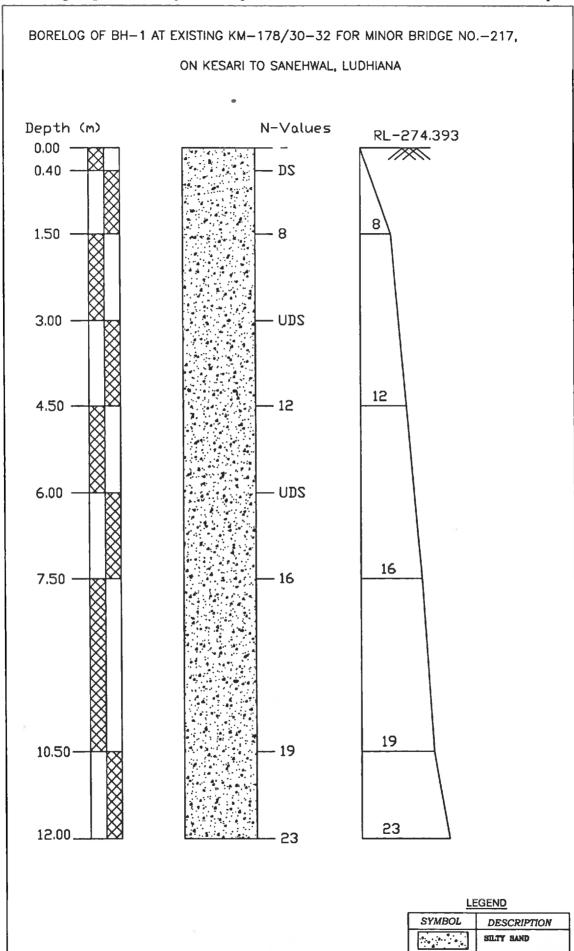


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																	70/1	AI CHAINAGE 178/30-32		
	Chainag	Chainage 178/30-31	31	Date of Testing	Loca	Location at	89	B.H. No.	Depth	Depth of Water Table	r Table	Ī	Termination Depth	upde			Surfax	Surface Elevation		
	Bridg	ge No. 217		27.12.2009 to 27.12.2009		_		-		07.50 m.	_		12.00mtr							
Observ-		Correction	Сопество	Soil		9	ain Size Di	Grain Size Distribution % wt retained	wt retain	2		Atter	Attenberg Limits %	% st	8.D.	M.C.	D.D.	Specific S	Shear Strength	figh
8		Factor		Description	į	å		Sand		ð	Gravel							Gravity		•
Z		ڻ	Z,	(Soil Group)	S S	H	Fine	Medium	Coarse	Fine	Coarse	LL	P.L.	1.7	gm/cc	38	gm/cc		c kg/cm²	федиве
•				Siliy Sand	3.68	20.28	83.25	10.52	0.65	1,82	0:00	13	불	2	ļ .					
SO			,	Silly Sand	3.45	19.99	82.42	12.36	0.52	126	000	R	₹°	g.						
60		1.43	11,44	Silly Sand	3.15	29.47	22.95	9.33	0.35	1.48	0.00	8	₹ E	ě	,				١.	
SON	<u></u>			Silty Sand	4.62	8.37	73.88	13.33	000	0.00	00:0	8	불	ē.	1.70	10.36	1.54	2.67	00.00	28.0
5		1.07	12.84	Sity Sand	4.56	11.49	60.10	23.85	0.00	0.00	0,0	8	불	å.						
son	10	,		Sifty Sand	4.12	42.74	35.69	16.64	0.36	0.45	0.00	8	Ä	g.	1.90	16.36	53.	28.2	0.00	28.5
16		0.89	14.24	Sifty Sand	3.96	12.51	16831	14.84	970	85.0	00.00	88	¥	å.						
19		0.78	14.82	Silty Sand	0.00	8.50	63.15	28.23	0.12	0.00	0.00	27	불	<u>a</u>		,	<u> </u>		 	
83		0.73	15.90	Silty Sand	3	9.6	75.80	10.05	000	0.00	000	28	护	<u>a</u>	,	,				
	10												1	1	-	1		- A-4	O N S U	CONSULTING Engineers Group Lid.



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 178 30-32	BH-1	
Туре	of footing			
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			•
4	Circular			
		•	L_	
Angle	of internal friction (o ")			25.00
	to a fact out on			26.00

20.00
0.00
0.73
0.00
1.70
1.80
1.50
3.00
3.0

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d = c \; N_c \, s_c \, d_c \, i_c + q \; (N_{q^-}1) \; s_q \, d_q \, i_q + (1/2) \; B \; \gamma \, N_{\gamma} s_{\gamma} \, d_{\gamma} i_{\gamma} W^*$

The ultimate net bearing capacity in case of local shear failure is given by $q_d^i = (2/3) \text{ c N'}_c \text{ s}_c \text{ d}_c \text{ i}_c + q \text{ (N'}_q\text{-1) s}_q \text{ d}_q \text{ i}_q + (1/2) \text{ B } \gamma \text{ N'}_\gamma \text{ s}_\gamma \text{ d}_\gamma \text{ i}_\gamma \text{W'}$

Where,

d = 1+ 0.2 (D/B)*SQRT(Na)

 $d_q = d_r = 1 \text{ for } \phi < 10^\circ$

 $d_q = d_{\gamma} = 1 + 0.1 (D_{\gamma}B)^*SQRT(N_{\phi}) \text{ for } \phi > 10^{\circ}$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

 ϕ for local shear failure = tan^{-1} (0.67 $tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

ф	26.00	φ'	18.10
N _c	22.60	N'c	13.36
N _q	12.21	N'q	5.46
N _y	13.18	N' ₇	4.35

Shape factors :

1 3.00 2 3.00	8.00 8.00	1.08	1.08	0.85
2 3.00	8.00	1.00		
	0.00	1.08	1.08	0.85
3 3.00	8.00	1.08	1.08	0.85
4 3.00	8.00	1.08	1.08	0.85

Depth factors:

S.no.	Depth(m)	Width(m)	dc	dq	d,
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.32	1.16	1.16
3	4.50	3.00	1.48	1.24	1.24
4	6.00	3.00	1.64	1.32	1.32

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1-\alpha/90)^{2}$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)			
				General shear	Local shear	Actual	
1	1.50	3.00	8.00	27.57	10.61	12.30	
2	3.00	3.00	8.00	29.61	11.39	13.21	
3	4.50	3.00	8.00	31.65	12.18	14.12	
.4	6.00	3.00	8.00	33.70	12.96	15.04	



ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)						
Location	Minor Bridge					
Chainage	178/30-32					
Bore Hole No.	1					

Footing Depth (m)	1.50
SBC (t/m2)	12.00
Average N value	13
Settlement for 10 t/m2 (mm)	25.00
Total Settlement (mm)	30.00
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	21.8

Footing Depth (m)	3.00
SBC (t/m2)	13.00
Average N value	13
Settlement 6 - 10 // 0 /	
Settlement for 10 t/m2 (mm)	25.00
Total Settlement (mm)	32.50
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	21.6

Footing Depth (m)	4.50
SBC (t/m2)	14.00
Average N value	14
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	30.80
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	18.2

Footing Depth (m)	6.00
SBC (t/m2)	15.00
Average N value	14
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	33.00
Depth Correction	0.63
Rigidity Factor	0.8
Corrected Settlement (mm)	16.6

Geo-technical Investigation

CHAPTER - 9

"Minor Bridge No. 218",

•Location - Existing Km. - 179/04-05



9.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x1.2x1.2

9.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics	
	0.00 to 0.60	Sandy Silt	Loose	
BH-1	0.60 to 7.50	Silty Sand	Loose	
<i>D</i> 11-1	7.50 to 12.00	Silty Sand	Medium Dense	
	Below 12.00	Sandy Silt with Clay	Medium Dense	

9.3 CHEMICAL ANALYSIS OF SOIL:

BORE	HOLE	CHEMICAL PROPERTIES					
No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity
	(m)			%	%	%	%
BH-1	3.00	8.30	NIL	0.0024	NIL	0.0012	0.051
	12.00	8.60	0.005	0.0021	NIL	0.0012	0.049

9.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	12.00	15.00

9.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

	pН	Chlorides	Sulphate	Organic	Inorganic	Acidity	Alkalinitu	Total	Conducti
Chemical Properties	Value	mg/lit	mg/lit	Matter mg/lit	Matter mg/lit	(ml)	(ml)	Disso. Solids	vity (µS/cm)
								(ppm)	
Test Result	7.0	66	120	129	659	0.4	4.5	801	1236
Requirement	Not	2000 for	400	200	3000	5 ml of	25 ml of	_	
as per 15:456	less	CC and				0.02	0.02		
/ Morth's	then	500 for				normal	normal		
	6.0	RCC				NaoH	H ₂ SO ₄		

9.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	06.00
BH-1	3.00	07.50
DU-1	4.50	09.00
	6.00	10.50

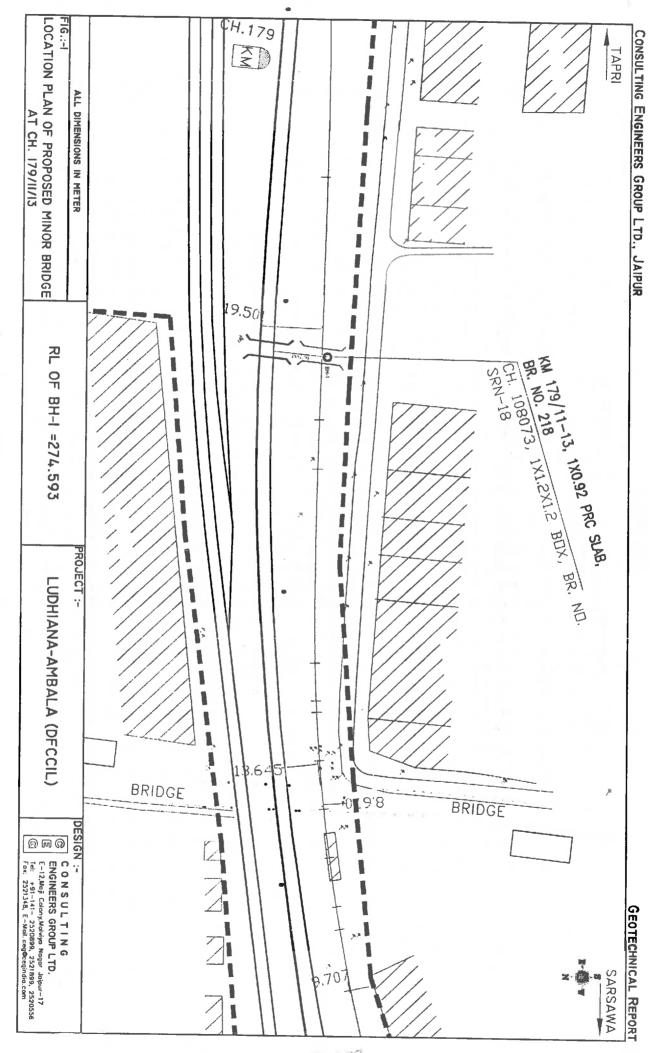
9.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

9.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 6.00 m from EGL

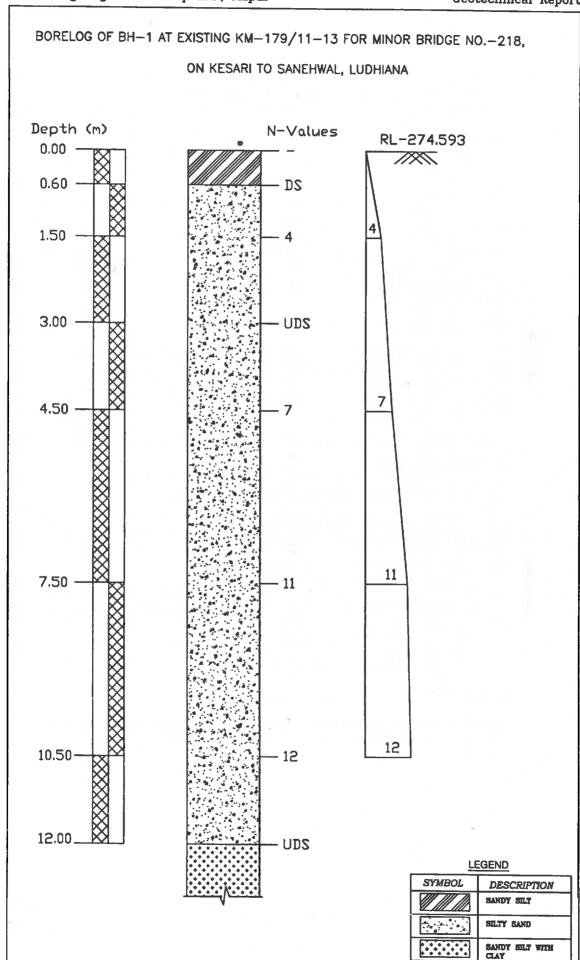
Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

:)											-	-			١				
	Chair	Chainage 179/04-05	99	Date of Testing	Location at	ion at	B.H.	B.H. No.	Depth	Depth of Water Table	Table	Тет	Termination Depth	epth			Surfac	Surface Elevation	5	
Project :	8	Bridge No. 218		26.12.2009 to 26.12.2009				1		07.00 m.			12.00mtr							
Depth	Observ-	Correction	Corrected	Soil		Grai	in Size Dist	Grain Size Distribution % wt retained	wt retaine	9		Attert	Atterberg Limits	% s1	B.D.	M.C.	D.D. S	Specific	Shear Strength	ngth
to the total	pe	Factor		Description	. ;	å		Sand		Gre	Gravel						0	Gravity	2 10/11/2	٠
GL (m)	z	ర్	z,	(Soil Group)	Clay	ž,	Fine	Medium	Coarse	Fine	Coarse	4	P.L.	P.I.	рт/сс	8	дт/сс			degree
0.00		,		Sandy Silt	2.36	9.04	70.15	18.45	0	0	0.00	24	Į.	<u>R</u>	,					•
0.60	Sa			Sity Sand	3.65	10.63	65.36	20.36	0	0	00.0	55	J	Ğ.						- ·
1.50	4	1.45	5.80	Silty Sand	3.85	13.25	90.99	16.84	00:00	0.00	0.00	56	NE NE	ď	•		,	•		
3.00	san		,	Sity Sand	0.00	8.05	33.37	58.58	0.00	0.00	00:00	58	Ę	₽.	1.71	9.94	1.55	2.67	0.00	28.0
4.50	7	1.08	7.56	Silty Sand	00.00	5.51	23.88	70.61	00:00	0.00	00:00	53	N.	₫.				,	,	
7.50	=	0.91	10.01	Silty Sand	0.00	4.27	29.35	66.38	00:00	0.00	0.00	30	N.	d. N	,	,	,	•		
10.50	12	0.80	9.60	Silty Sand	0.00	6.08	39.64	52.05	1.03	1.20	0.00	8	Ę	Q.						
12.00	san			Sandy Silt with Clay	14.62	51,50	22.15	1.36	0.45	9.92	0.00	æ	24	12	1.91	21.89	1.56	2.64	0.15	18.0
																		OBC.	Engineers	Engineers Grup Lid.

0



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 179 11-13	BH-1	
Type	of footing			
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			
4	Circular			
Angle	of internal friction (φ °)	_		28.00
Cohes	ion (c in t/m2)			0.00
Void ra	atio (e)			0.72
Directi	on of load with vertical (°)			0.00
Densit	y of surcharge (l/m³)			1.70
Densit	y of foundation soil (t/m3)			1.75
Depth	of water table(m)			1.50

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	1.20	8.00
2	3.00	1.20	8.00
3	4.50	1.20	8.00
4	6.00	1.20	8.00

SHEAR FAILURE CRITERIA

Factor of safety

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,i_c+q\;(N_q-1)\;s_q\,d_q\,i_q+(1/2)\;B\;\gamma\,N_\gamma\,s_\gamma d_\gamma\,i_\gamma W'$

The ultimate net bearing capacity in case of local shear failure is given by $q'_d = (2/3) \ c \ N'_e \ s_c \ d_e \ i_e + q \ (N'_{q} \ ^{-1}) \ s_q \ d_q \ i_q + (1/2) \ B \ \gamma \ N'_\gamma s_\gamma d_\gamma i_\gamma W'$

Where.

$$\begin{split} &d_c = 1 + 0.2 \; (D/B)^* SQRT(N_\phi) \\ &d_q = d_\gamma = 1 \; \text{for} \; \phi < 10^\circ \\ &d_q = d_\gamma = 1 + 0.1 \; (D/B)^* SQRT(N_\phi) \; \; \text{for} \; \phi > 10^\circ \\ &N_\phi = tan^2 (\pi/4 + \phi/2) \\ &\phi' \; \text{for local shear failure} = tan^{-1} \; (\; 0.67 \; tan\phi \;) \end{split}$$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

3.00

Bearing capacity factors :

ф	28.00	φ'	19.61
N _c	26.37	N'c	14.53
Nq	15.30	N' _q	6.21
N ₇	17.79	N' _y	5.18

Shape factors :

S.no.	Width(m)	Length (m)	S _c	S,	S,
1	1.20	8.00	1.03	1.03	0.94
2	1.20	8.00	1.03	1.03	0.94
3	1.20	8.00	1.03	1.03	0.94
4	1.20	8.00	1.03	1.03	0.94

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d _q	d,
1	1.50	1.20	1.42	1.21	1.21
2	3.00	1.20	1.83	1.42	1.42
3	4.50	1.20	2.25	1.62	1.62
4	6.00	1.20	2.66	1.83	1.83

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1 - \alpha / 90)^2$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)		Z _w /B	W'
1	1.50	1.20		0.00	0.50
2	3.00	1.20	•	-1.25	0.50
3	4.50	1.20		-2.50	0.50
4	6.00	1.20		-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	1.20	8.00	15.64	5.43	6.96
2	3.00	1.20	8.00	18.33	6.37	8.16
3	4.50	1.20	8.00	21.02	7.31	9.36
4	6.00	1.20	8.00	23.72	8.24	10.56



ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)					
Location	Minor Bridge				
Chainage	179 /4 -6				
Bore Hole No.	1				

Footing Depth (m)	1.50
SBC (t/m2)	6.00
Average N value	7
Settlement for 10 t/m2 (mm)	64.00
Total Settlement (mm)	38.40
Depth Correction	0.8
Rigidity Factor	0.8
Corrected Settlement (mm)	24.6

Footing Depth (m)	3.00
SBC (t/m2)	7.50
Average N value	8
Settlement for 10 t/m2 (mm)	56.00
Total Settlement (mm)	42.00
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	24.5

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Footing Depth (m)	4.50
SBC (t/m2)	9.00
Average N value	9
Settlement for 10 t/m2 (mm)	42.00
, , ,	
Total Settlement (mm)	37.80
Depth Correction	0.67
Rigidity Factor	0.8
Corrected Settlement (mm)	20.3

Footing Depth (m)	6.00
SBC (t/m2)	10.50
Average N value	9
Settlement for 10 t/m2 (mm)	42.00
Total Settlement (mm)	44.10
Depth Correction	0.67
Rigidity Factor	0.8
Corrected Settlement (mm)	23.6

CHAPTER - 8

"Minor Bridge No. 221A",

Location - Existing Km. - 182/00-01



8.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge No. 221A

8.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 8.50m below EGL.

Subsurface profile at the site

BOREHOLE Depth No. (m)		Type of Soil/Rock	Soil/Rock Characteristics	
	0.00 to 3.00	Filled up Strata	Loose	
BH-1	3.00 to 4.50	Silty Sand with Gravels	Loose	
	4.50 to 12.00	Silty Sand	Medium Dense	

8.3 CHEMICAL ANALYSIS OF SOIL:

BORE	HOLE		CI	HEMICAL I	PROPERTII	ES	
No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity
	(m)	· •	ŀ	%	%	%	%
777.4	3.00	8.60	NIL	0.0026	NIL	0.0011	0.057
BH-1	9.00	8.80	NIL	0.0020	NIL	0.0011	0.049

8.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
777.4	6.00	NIL
BH-1	9.00	NIL

8.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties			Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	6.5	79	142	113	669	0.4	3.9	792	1262
Requirement as per IS 456 / Morth's		2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	-	-

8.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	3.00	12.00
BH-1	• 4.50	14.00
	6.00	16.00

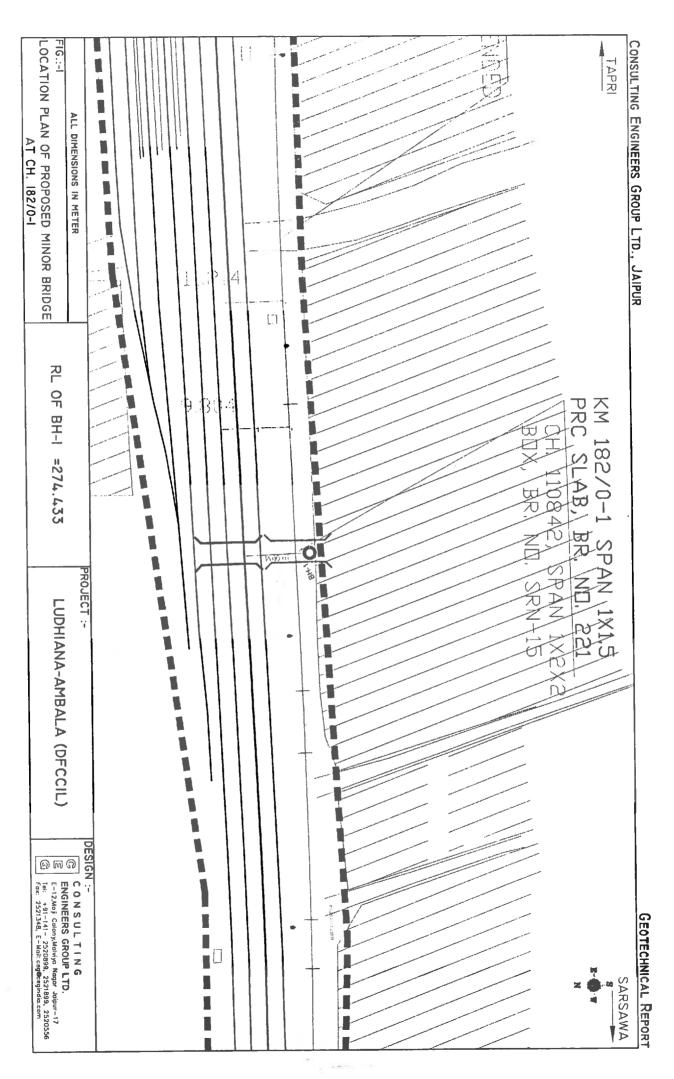
8.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

8.8 RECOMMENDATIONS

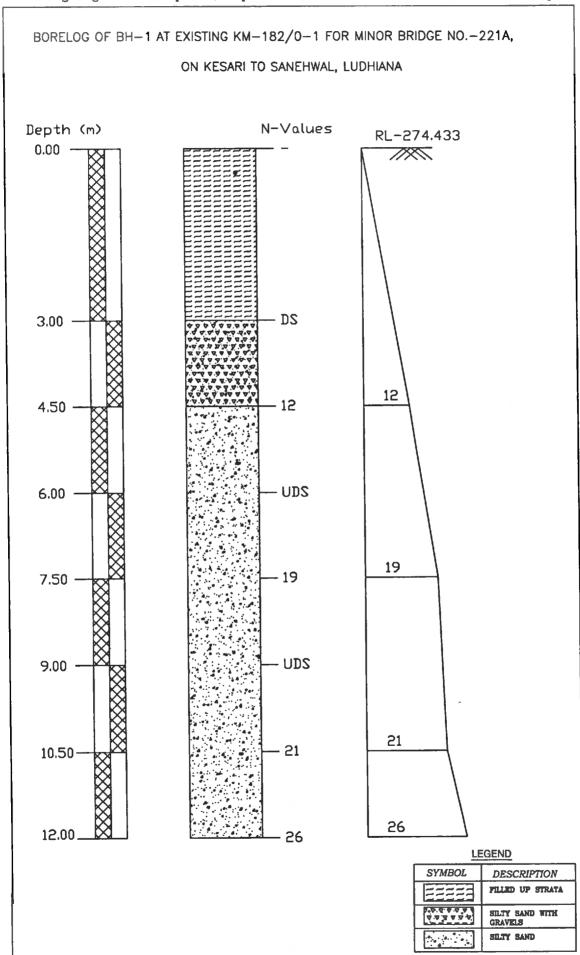
(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

- Gran		B.H. No.	Depth	Depth of Water Table	Table	Termin	Termination Depth	f f	-		Surface Elevation	wation	
Graff	-			08.50 m.		12	12.00mtr						
	n Size Dist	Grain Size Distribution % wt retained	w retained			Atterbe	Atterberg Limits %	+	B.D. N	M.C.	D.D. Specific	ic Shear Strength	trenath
		Sand		Gravel		-		+	+-	+		_	
# 150 m	Fine	Medium	Coarse	Fine	Coarse	- -	P.L	P.I.	gm/cc	8	om/cc	c kg/cm²	degrap
						-	 .					ļ.	
9. Ci	88	16.26	0.36	8.35	0.00	KS .	¥	<u>e</u>	,				
13.78	60.25	20.15	0.45	2.16	0.00	24	Į.	9	+-	'	ļ ·	ļ. —	
13.46	82.58	18.35	51.7	0.65	0.00	8	륄	P P	1.81	11.52	1.62 2.67	0.00	28.0
18.32	28.52	17.26	0.52	1,28	0.00	8	1	<u>a</u>	-	:	.	,	
11.72	63.26	20.36	0.36	-	-	 		-	+		2.64	0.00	28.0
16.35	22.82	19.84			-	-	-	-	-	<u> </u>	<u> </u>		
17.78	26.92	17.38				 -			-	<u> </u>	·		
						-		-	-		-	ENGLISH SE	U L T I N Group L
	11.72		59.26 20.36 28.23 19.84 59.32 17.36	63.26 20.36 0.36 28.23 19.84 0.41 59.32 17.36 1.1	28.23 19.84 0.41 0.66 59.32 17.36 1.1 0.75	28.23 19.84 0.41 0.66 0.00 59.32 17.36 1.1 0.75 0.00	28.23 19.84 0.41 0.66 0.00 25 59.32 17.36 1.1 0.75 0.00 22	63.26 20.36 0.62 0.00 24 NIL 28.23 19.84 0.41 0.66 0.00 25 NIL 59.32 17.38 1.1 0.75 0.00 22 NIL	63.26 20.36 0.36 0.00 24 NIL NP 28.23 19.84 0.41 0.66 0.00 25 NIL NP 59.32 17.38 1.1 0.75 0.00 22 NIL NP	63.26 20.36 0.36 0.62 0.00 24 NIL NP 1.88 28.23 19.84 0.41 0.66 0.00 25 NIL NP -	63.26 20.36 0.62 0.00 24 NIL NP 1.88 19.35 28.23 19.84 0.41 0.66 0.00 25 NIL NP -	63.26 20.36 0.36 0.62 0.00 24 NIL NP 1.88 19.35 1.58 2.64 28.23 19.84 0.41 0.66 0.00 25 NIL NP	63.26 20.36 0.36 0.62 0.00 24 NIL NP 1.88 19.35 1.58 2.64 28.23 19.84 0.41 0.66 0.00 25 NIL NP



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

^L	182	
- Cin	102	111-1

	UII 102 U-1	KH-1	
of footing		5.1.	
Continuous Strip			
Rectangular		Rectangular	2
Square		···otungulai	-
Circular			
of internal friction (¢°)			28.00
ion (c in t/m2)			0.00
itio (e)			0.65
on of load with vertical (°)			0.00
	•		_
			1.70
			1.81
			1.50
or sarety			3.00
	Continuous Strip Rectangular Square Circular of internal friction (\$\phi^{\alpha}\$) ion (c in 1/m2)	of footing Continuous Strip Rectangular Square Circular of internal friction (\$\phi^{\alpha}\$) ion (c in 1/m2) tio (e) on of load with vertical (\$^\alpha\$) of surcharge (1/m3) of foundation soil (1/m3) of water table(m)	Continuous Strip Rectangular Square Circular of internal friction (\$\phi^0\$) ion (c in \(\text{in m}^3 \)) of surcharge (t/m³) of foundation soil (t/m³) of water table(m)

3.00	1.00	Length (m)
0.00	1.20	8.00
4.50	1.20	8.00
6.00	1.20	8.00
		4.50 1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $\mathbf{q}_{d} = c \; N_{c} \, s_{c} \, d_{c} \, i_{c} + q \, (N_{q} \cdot 1) \; s_{q} \, d_{q} \, i_{q} + (1/2) \; \mathbf{B} \; \gamma \, N_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W^{*}$

The ultimate net bearing capacity in case of local shear failure is given by $q_{d}^{\prime} = (2/3) \ c \ N_{c}^{\prime} s_{c} \ d_{c} \ i_{c} + q \ (N_{q}^{\prime} - 1) \ s_{q} d_{q} \ i_{q} + (1/2) \ B \ \gamma \ N_{\gamma}^{\prime} s_{\gamma} d_{\gamma} i_{\gamma} W^{\prime}$

Where,

d_c = 1+ 0.2 (D/B)*SQRT(N_e) $d_q = d_y = 1 \text{ for } \phi < 10^\circ$ $d_q = d_\gamma = 1 + 0.1 \; (D_r/B)^* SQRT(N_\phi) \; \; for \; \phi > 10^\circ$ $N_{\phi} = \tan^2(\pi/4 + \phi/2)$ φ' for local shear failure = tan⁻¹ (0.67 tanφ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

ſ	ф	28.00
1	N _c	26.37
1	N _a	15.30
1	N _Y	· 17.79

φ'	19.61
N' _c	14.53
N' _q	6.21
N' _y	5.18

Shape factors:

Width(m)	Length (m)	Sc	S ,	S,
1.20	8.00	1.03	1.03	0.94
1.20	8.00	1.03	1.03	0.94
1.20	8.00	1.03	1.03	0.94
	1.20 1.20	1.20 8.00 1.20 8.00	1.20 8.00 1.03 1.20 8.00 1.03	1.20 8.00 1.03 1.03 1.20 8.00 1.03 1.03

Depth factors:

S.no.	Depth(m)	Width(m)	dc	dq	dy
1	3.00	1.20	1.83	1.42	1.42
2	4.50	1.20	2.25	1.62	1.62
3	6.00	1.20	2.66	1.83	1.83

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_0 = (1 - \alpha / 90)^2$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z"/B	W'
1	3.00	1.20	-1.25	0.50
2	4.50	1.20	-2.50	0.50
3	6.00	1.20	-3.75	0.50
			•	

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	3.00	1.20	8.00	18.47	6.41	12.44
2	4.50	1.20	8.00	21.19	7.35	14.27
3	6.00	1.20	8.00	23.90	8.30	16.10



0

Settlement Calculation As per IS 8009 (Part 1)				
Location	Minor Bridge			
Chainage	182/00-01			
Bore Hole No.	1			

Footing Depth (m)	3.00
SBC (t/m2)	12.00
Average N value	13
Settlement for 10 t/m2 (mm)	20.00
Toatl Settlement (mm)	24.00
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	14.2

Footing Depth (m)	4.50
SBC (t/m2)	14.00
Average N value	14
Settlement for 10 t/m2 (mm)	18.00
Toatl Settlement (mm)	25,20
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	13.7

Footing Depth (m)	6.00
SBC (t/m2)	16.00
Average N value	16
Settlement for 10 t/m2 (mm)	15.00
Toatl Settlement (mm)	24.00
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	13.1



CHAPTER - 7

"Minor Bridge No. 223",

Location - Existing Km. - 182/27-29



7.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x 3 x 3

7.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 8.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
	0.00 to 3.00	Silty Sand with Gravels	Loose
BH-1	3.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

7.3 CHEMICAL ANALYSIS OF SOIL:

BOR	EHOLE	CHEMICAL PROPERTIES					
No.	Depth (m)	pН	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
DIV 4	3.00	8.10	NIL	0.0024	NIL	0.0018	0.026
BH-1	6.00	8.30	NIL ·	0.0026	NIL	0.0019	0.021

7.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
D114	3.00	NIL
BH-1	6.00	NIL

7.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	7.3	60	129	119	663	0.6	4.5	792	1236
Requirement as per IS: 456 / Month's	1	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	•	-

7.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	10.00
DII 1	3.00	16.00
BH-1	4.50	16.50
	6.00	17.00

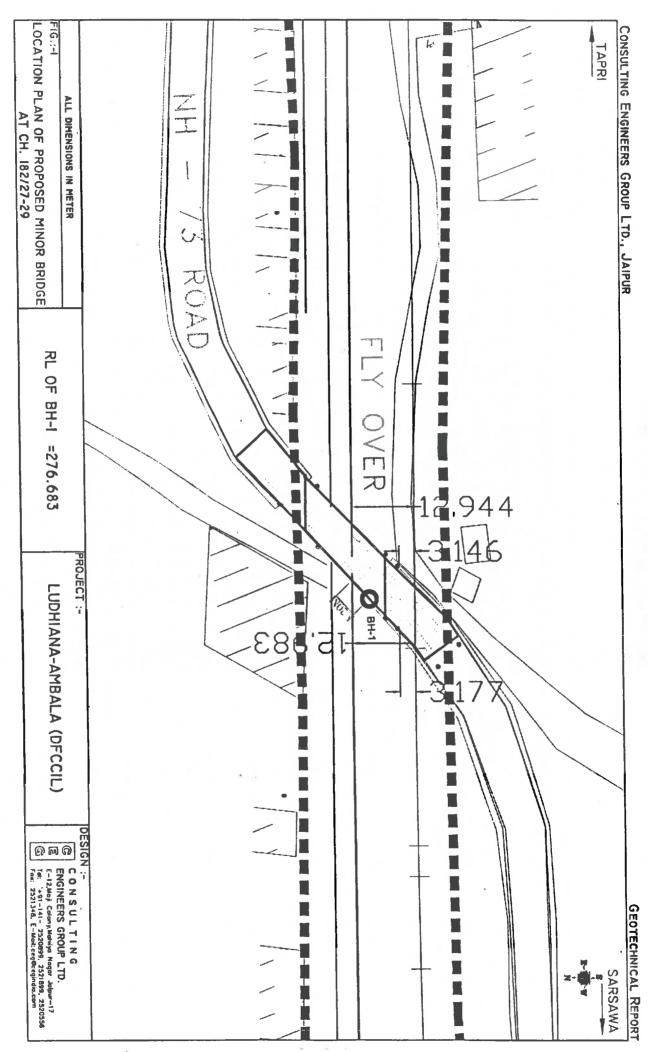
7.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

7.8 RECOMMENDATIONS

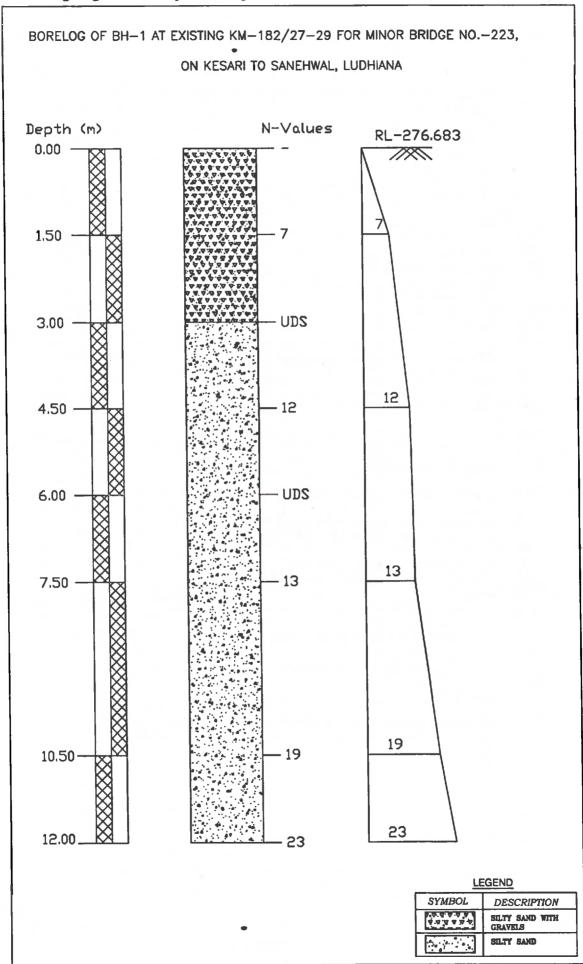
(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 3.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

			Shear Strength	4	degree	,	'	27.0		29.0			,	CONSULTING
ion				c ko/cm²			,	0.00		0.00	•	•		0
Surface Elevation			Specific	Gravity			,	2.67	·	2.65		.]	,	
Surfa			D.D.		дш/сс		'	1.58		1.61		,	,	
			₩.C.		96	,	,	11.69		15.23	,	•		
			B.D.		gm/cc			1.76	'	1.86	,			
Depth			nits %		P.I.	S Q	• <u>&</u>	Ž	g.	Ž	ğ	2	2	
Termination Depth		12.00mtr	Atterberg Limits %		P.L.	NI	NIL	NE	Nil	NIL	튙	불	불	
Tem			Atte		크	ន	22	24	25	24	83	23	83	
Table				Gravel	Coarse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Deoth of Water Table	ח אי מושי	08.00 m.		ğ	Fine	7.15	6.95	2,46	0.00	0.00	0.00	00:00	0.00	
Deoth	Debu		wt retaine		Coarse	0.56	0.75	0	0.00	0.23	0.09	0.19	60.09	
2	2	1	Grain Size Distribution % wt retained	Sand	Medium	15.68	17.62	16.35	19.52	17.86	13.95	13.63	22.15	
H. R.	יי ני		n Size Dis		Fine	60.25	55.42	56.85	54.46	53.49	50.21	51.70	53.31	
# SO	on at		Grai		ii.	13.10	16.11	20.49	22.23	24.75	32.49	30.62	20.33	
l ocation at	Locati	_			Clay	3.26	3.15	3.85	3.79	3.67	3.26	38.8	4,12	
Date of Tanting	Date of Testing	24,12,2009 to 24,12,2009	Soil	Description	(Soil Group)	Sity Sand with Gravels	Sifty Sand with Gravels	Silty Sand	Silty Sand	Silty Sand	Saty Sand	Silty Sand	Sity Sand	
			Corrected		ž		10.15		12.96		11.70	15.01	16.01	
	18ge 182/27-2	Bridge No. 223	Correction		5		1.45		1.08		0.90	0.79	0.74	
	Chair	B	Observ-	8	Z	,	• ′	san	12	san	13	<u>~</u>	8	
		Project :	Deoth	to the	GL (m)	0.00	1.50	3.00	4.50	6.00	7.50	10.50	12.00	



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 182 27-29	BH-1	
Туре с	of footing	•	-	
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			
4	Circular		L	
Angle	of internal friction (¢°)			27.00
_	ion (c in t/m2)			0.00
	atio (e)			0.69
	ion of load with vertical (°)			0.00

actor of safety	,		3.00
S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Density of surcharge (t/m3)

Depth of water table(m)

Density of foundation soil (1/m3)

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,i_c+q\;(N_q\text{--}1)\;s_q\,d_q\,i_q+(1/2)\;B\;\gamma\;N_\gamma s_\gamma d_\gamma i_\gamma W$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3) c N'_c s_c d_c i_c + q (N'_q-1) s_q d_q i_q + (1/2) B \gamma N'_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_{\phi})$

 $d_q = d_y = 1$ for $\phi < 10^\circ$

 $d_q = d_{\gamma} = 1 + 0.1 (D_f/B)^*SQRT(N_{\phi}) \text{ for } \phi > 10^{\circ}$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

 ϕ for local shear failure = tan^{-1} (0.67 $tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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1.70

1.76

1.50

Bearing capacity factors :

Г	ф	27.00
	N _c	24.49
	N _q	13.76
	N _y	15.49

φ'	18.85
N'c	13.94
N' _q	5.83
N' _v	4.76

Shape factors:

S.no.	Width(m)	Length (m)	S _c	Są	S,
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d_q	d _r
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.24	1.24
4	6.00	3.00	1.65	1.33	1.33

Inclination factors :

$i_c = (1 - \alpha / 90)^2$	$i_a = (1-\alpha/90)^2$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	31.48	11.48	17.48
2	3.00	3.00	8.00	33.85	12.35	18.80
3	4.50	3.00	8.00	36.23	13.21	20.12
4	6.00	3.00	8.00	38.60	14.08	21.44
			•			



Se	ttlement Calculation	As per IS 800	09 (Part 1)	
Location	Minor Bridge			
Chainage	182/27-29			
Bore Hole No.	1			

Footing Depth (m)	1.50
SBC (t/m2)	10.00
Average N value	12
Settlement for 10 t/m2 (mm)	23.00
Total Settlement (mm)	23.00
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	16.7
	9

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	12
Settlement for 10 t/m2 (mm)	23.00
Total Settlement (mm)	36.80
Depth Correction	0.82
Rigidity Factor	0.8
Corrected Settlement (mm)	24.1

Footing Depth (m)	4.50
SBC (t/m2)	16.50
Average N value	13
114-514-514-4414-6	
Settlement for 10 t/m2 (mm)	25.00
Total Settlement (mm)	41.25
Depth Correction	0.75
Rigidity Factor	0.8
Corrected Settlement (mm)	24.8

Footing Depth (m)	6.00
SBC (t/m2)	17.00
Average N value	13
Settlement for 10 t/m2 (mm)	25.00
Total Settlement (mm)	42.50
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	23.1

CHAPTER - 6

"Minor Bridge No. 226",

Location - Existing Km. - 183/27-184/3



6.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x 2 x 2

6.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.00m below EGL.

Subsurface profile at the site

Substitute profite at the bite					
BOREHOLE	Depth	Type of Soil/Rock	Soil/Rock		
No.	(m)		Characteristics		
	0.00 to 3.00	Silty Sand	Loose		
BH-1	3.00 to 4.50	Sandy Silt with Clay	Loose		
	4.50 to 12.00	Sandy Silt with Clay	Medium Dense		

6.3 CHEMICAL ANALYSIS OF SOIL:

	BORE	HOLE		CI	HEMICAL I	PROPERTII	ES	
Г	No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity
		(m)	-		%	%	%	%
Г	DII 1	3.00	7.80	NIL	0.0020	NIL	0.0011	0.011
L	BH-1	6.00	8.20	NIL	0.0016	NIL	0.0011	0.013

6.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
DIT 1	3.00	13.00
BH-1	6.00	13.00

6.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	7.1	73	143	128	673	0.3	2.6	812	1265
Requirement	Not	2000 for	400	200	3000	5 ml of	25 ml of	-	-
as per IS: 456	less	CC and				0.02	0.02		
/ Morth's	then	500 for				normal	normal	-	
	6.0	RCC				NaoH	H ₂ SO ₄		

6.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	08.00
777.4	3.00	09.50
BH-1	4.50	11.00
	• 6.00	12.00

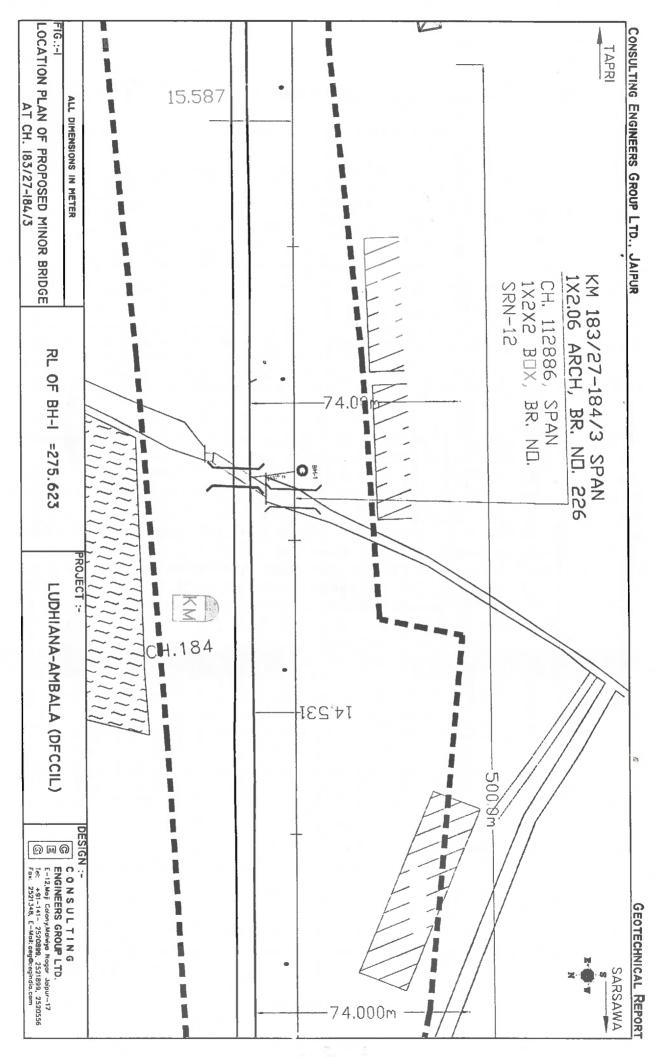
6.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

6.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 6.00 m from EGL

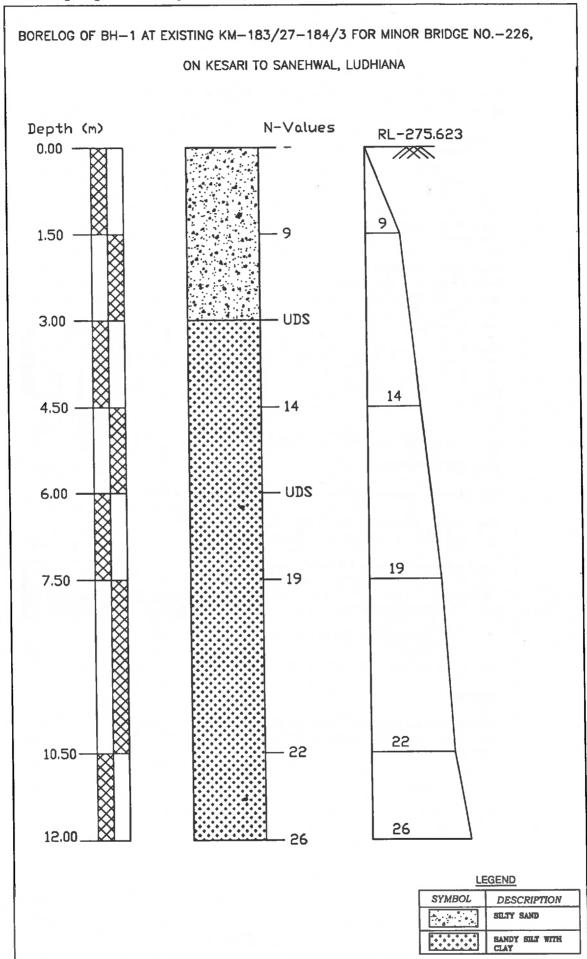
Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Clay Silt Fine B.H. No. Depth of Water Table Termination Depth Austroay Limits % B.D. M.C. D.D. Specific Shear Strength D.D. Specific S				 				-	_	-			_				
Clear Silit Sand Coarse Fine Ö	Date of Testing	Location	n art	В.Н.	No.	Depth o	Water T	able	Termina	lon Dept	_		Sur	ace Eleva	lion		
Ciby Silk Sand Coarse Fine	90	23.12.2009 to 23.12.2009	-		1		0	7.00 m.		12.	Omtr	-					
Cluy Sill Hine Anedium Coarse Fine Coarse LL P.L P.L P.L P.L P.L Gravel Coarse LL P.L P.L P.L P.L P.L P.L P.L P.L P.L	3			Grain	Size Distr	ribution % w	n retained			Atterber	Limits 9	-					rength
CLBY Silk Fine Medium Coarse Fine Coarse L.L. P.L.	Description	_				Sand		Grav		_		\dashv	_		Gravity	c ko/cm²	
3.42	(Soil Group)		Clay	i i	Fine	1—1	Coarse	\vdash	coarse	-	-			gm/c			degree
3.42 29.02 64.91 2.65 0.00 0.00 25 NIL NP .	Silty Sand		2.69	30.74	63.42	3.15	0.00	0.00	0.00				·	•	•		•
10.65 67.74 16.35 2.16 0.95 2.15 0.00 31 22 9 1.76 13.26 1.55 2.64 0.1 9,42 73.70 10.86 1.07 0.78 4.36 0.00 31 23 8 -	Silty Sand		3.42	29.02	64.91	2.65	00:00	00:00	0.00						•		,
9.42 73.70 10.66 1.07 0.78 4.36 0.00 31 23 8 - </td <td>Sandy Silt with Clay</td> <td>lay</td> <td>10.65</td> <td>67.74</td> <td>16.35</td> <td>2.16</td> <td>0.95</td> <td>2.15</td> <td>0.00</td> <td>31</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>9.</td> <td>20.0</td>	Sandy Silt with Clay	lay	10.65	67.74	16.35	2.16	0.95	2.15	0.00	31						9.	20.0
10.85 65.05 20.34 2.16 0.36 1.24 0.00 32 23 9 1.92 18.42 1.62 2.62 0.11 7.63 65.37 23.37 3.46 0.17 0.00 0.00 28 21 7 - <td< td=""><td>Sandy Sitt with Clay</td><td>ay</td><td>9.42</td><td>73.70</td><td>10.66</td><td>1.07</td><td>0.79</td><td>4.36</td><td>0.00</td><td>31</td><td>ឌ</td><td></td><td></td><td></td><td></td><td>•</td><td>'</td></td<>	Sandy Sitt with Clay	ay	9.42	73.70	10.66	1.07	0.79	4.36	0.00	31	ឌ					•	'
7.83 65.37 23.37 3.46 0.17 0.00 0.00 28 21 7 · · · · · · · · · · · · · · · · · ·	Sandy Silt with Clay	ay	10.85	65.05	20.34	2.16	0.36	1.24	0.00	32	23					0.11	19.0
10.00 73.72 14.85 1.12 0.31 0.00 0.00 29 20 9 - · · · · · · · · · · · · · · · · · ·	Sandy Silt with Clay	ау	7.63	65.37	25.37	3.46	0.17	0.00	0.00	88	12				-	.	•
6.68 80.15 12.17 1.00 0.00 0.00 0.00 28 22 6 · · · · ·	Sandy Sift with Clay	Clay	10.00	73.72	14.85	1.12	0.31	0.00	0.00	53	22				,		,
	Sandy Silt with Clay	Clay	6.68	80.15	12.17	1.00	0.00	0.00	0.00	8	ผ					•	

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Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

	<u> </u>		Ch 183 27- 184 3		BH-1
Type o	l footing				
1	Continuous Strip				
2	Rectangular			Rectangular	2
3	Square				
4	Circular	ñ			
					27.00

Angle of internal friction (\$\phi^\circ\$)		27.00
Cohesion (c in Vm2)		0.00
Void ratio (e)		0.75
Direction of load with vertical (°)		0.00
_		1.70
Density of surcharge (t/m³)		1.90
Density of foundation soil (t/m³)	•	1.50
Depth of water table(m)		3.00
Factor of safety		0.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	2.00	8.00
·			

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_{d}=c\;N_{c}\;s_{c}\;d_{c}\;i_{c}+q\;(N_{q}\text{-}1)\;s_{q}\;d_{q}\;i_{q}+\{1/2\}\;B\;\gamma\;N_{\gamma}s_{\gamma}d_{\gamma}i_{\gamma}W'$

The ultimate net bearing capacity in case of local shear failure is given by $q'_d=(2/3)~c~N'_c~s_c~d_c~i_c+~q~(N'_q-1)~s_q~d_q~i_q+(1/2)~B~\gamma~N'_\gamma s_\gamma d_r i_r~W'$

Where,

$$\begin{split} &d_{c}=1+0.2\;(D/B)^{*}SQRT(N_{\phi})\\ &d_{q}=d_{\gamma}=1\;\text{for}\;\phi<10^{\circ}\\ &d_{q}=d_{\gamma}=1+0.1\;(D_{f}B)^{*}SQRT(N_{\phi})\;\;\text{for}\;\phi>10^{\circ}\\ &N_{\phi}=tan^{2}(\pi/4+\phi/2)\\ &\phi'\;\text{for local shear failure}=tan^{\cdot1}\;(\;0.67\;tan\phi\;) \end{split}$$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.



Bearing capacity factors :

ф	27.00	Φ'	18.85
N _c	24.49	N' _c	13.94
N _q	13.76	N' _q	5.83
N _y	15.49	N' _y	4.76

Shape factors :

S.no.	Width(m)	Length (m)	S.	S_q	S,
-1	2.00	8.00	1.05	1.05	0.90

Depth factors :

1 1.50 2.00 • 1.24 1.12	
	1.12

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1 - \alpha / 90)^2$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	W'
1	1.50	2.00	0.00	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	2.00	8.00	21.99	7.98	7.98



Calculation of SBC for shallow foundations as per IS: 6403 - 1981 INPUT DATA

		Ch 183 27- 184 3		BH-1
Туре о	l footing			
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			
4	Circular			
Angle	of internal friction (φ°)			19.00
•	ion (c in t/m2)			1.10
Void ra	•			0.70
	on of load with vertical (°)			0.00
	y of surcharge (t/m³)			1.70
	y of foundation soil (1/m³)			1.90
2311311	,			4.50

S.no.	Depth (m)	Width (m)	Length (m)
		0.00	8.00
1	3.00	2.00	
2	4.50	2.00	8.00
3	6.00	2.00	8.00

SHEAR FAILURE CRITERIA

Depth of water table(m)

Factor of safety

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_{o}=c\;N_{o}\;s_{c}\;d_{c}\;i_{c}+q\;(N_{q}-1)\;s_{q}\;d_{q}\;i_{q}+\{1/2\}\;B\;\gamma\;N_{\gamma}s_{\gamma}d_{\gamma}i_{\gamma}W'$

The ultimate net bearing capacity in case of local shear failure is given by $q_d^\prime = (2/3) \ c \ N_c^\prime s_c \ d_c \ i_c + q \ (N_q^{-1}) \ s_q \ d_q \ i_q + (1/2) \ B \ \gamma \ N_\gamma^\prime s_\gamma \ d_\gamma i_\gamma W^\prime$

Where,

 $d_c = 1 + 0.2 (D_f/B)^*SQRT(N_\phi)$ $d_q = d_\gamma = 1 \text{ for } \phi < 10^\circ$

 $d_q = d_y = 1 + 0.1 (D_f/B)^*SQRT(N_\phi)$ for $\phi > 10^\circ$

 $N_0 = \tan^2(\pi/4 + \phi/2)$

 ϕ^{*} for local shear failure = tan^{-1} ($0.67~tan\phi$)

<u>OUTPUT</u>

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.



1.50

3.00

Bearing capacity factors :

ф	19.00	φ'	12.99
N _c	14.06	N' _c	9.92
Nq	5.91	N' _q	3.35
N _y	· 4.84	N' _y	2.08

Shape factors:

S.no.	Width(m)	Length (m)	 Sç	S_q	S,
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90
3	2.00	8.00	1.05	1.05	0.90

Depth factors:

S.no.	Depth(m)	Width(m)	dc	dq	d _γ
1	3.00	2.00	1.42	1.21	1.21
2	4.50	2.00	1.63	1.32	1.32
3	6.00	2.00	1.84	1.42	1.42

Inclination factors :

1	$i_c = (1-\alpha/90)^2$	$i_0 = (1-\alpha/90)^2$	$i_v = (1 - \alpha / \phi)^2$
Í	1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	W'
1	3.00	2.00	-0.75	0.50
2	4.50	2.00	-1.50	0.50
3	6.00	2.00	-2.25	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	3.00	2.00	8.00	16.43	7.72	9.90
2	4.50	2.00	8.00	18.33	8.61	11.04
3	6.00	2.00	8.00	20.22	9.50	12.18



Settlement Calculation A	s per IS 8009 (Part 1)
Location	Minor Bridge
Chainage	183/27-184/3
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	8.00
Average N value	14
Settlement for 10 t/m2 (mm)	20.00
Settlement (mm) for SBC	16.00
Depth Correction	0.83
Corrected Settlement (mm)	13.3

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Settlement Calculation As per IS 800	09 (Part 1)			M	linor Brid	ige Ch. 183,	/27-184/3
BH No. (A1)							
Depth of foundation		=		3.0	m		
Length of footing (L)		-		8.0	m		
Width of footing (B)		=		2.0	m		
initial effective stress at mid of layer	Po	=		8.1	t/m ²		
Concentrated load P		=		9.50	t/m²		
Incerase in pressure at mid of layer	ΔΡ	=		$P \times I_B$			
		$I_B =$		0.21			
	ΔΡ	-		2.0	t/m ²		
Compression Index	Cc	=		0.14			
Thickness of clay layer	Н	=		3	m		
Initial Void ratio	eo	=		0.75			
	Po + Δp Po		=	1.246296296			
Settlement of clay layer	$S_{\mathbf{f}}$		=	Cc 1+ eo	- Н	log 10	Po + ΔI Po
	S_f		=	0.022949113	m		
		_		22.9	mm		
Correction for Depth and Rigidity of	foundation	n on tota	al settle				
Depth Factor Calculation							
	D 7 LB)/	√0.5	=	0.75			
	D/ LbJ			0.75			
D = Depth of Foundation							
	L/B		=	4.00			
				. ==			
Depth Factor			=	0.78			
				of Rigid founda			
Rigidity Factor =	Total Settle	ement a	it the co	entre of Flexible	foundati	on	
0.0							
= 0.8							
Pore Pr. Correction= N.A.		-		C. v Di	CVDE		
	S _{r2}	=		$S_t \times D.1$ 14.3	F.x R.F. mm		



,							
Settlement Calculation As per IS 800	9 (Part 1)			N	1inor Bri	dge Ch. 183	3/27-184/3
BH No. (A1)							
Depth of foundation		=0.01		4.5	m		
Length of footing (L)		=		8.0	m		
Width of footing (B)		=		2.0	m		
Initial effective stress at mid of layer	Po	572		11.4	t/m²		
Concentrated load P		=		11.00	t/m²		
Incerase in pressure at mid of layer	ΔΡ	=		$P \times I_B$			
•		/ B =		0.21			
	ΔΡ	=		2.3	t/m²		
Compression Index	Cc_	=		0.14			
Thickness of clay layer	н	=		3	m		
Initial Void ratio	eo	=		0.75			
	Po + Δp Po		=	1.20263157	9		
Settlement of clay layer	S_{f}		=	Cc 1+ eo	— н	log 10	$\frac{Po + \Delta P}{Po}$
	S _f		=	0.01923182	25 m		
		=		19.2	mm		
Correction for Depth and Rigidity of Depth Factor Calculation	foundatio	n on tota	al settle	ement			
	D/LB)	∧ ^{0.5}	=	0.89			
D = Depth of Foundation							
	L/B	}	=	4.00			
Depth Factor			=	0.74			
	• Tal	al Cattle	mant	of Rigid found	ation		
Rigidity Factor =	Total Settle	ement a	t the co	entre of Flexible	e founda	tion	-
= 0.8							
Pore Pr. Correction= N.A.							
Total Settlement		=		$S_f \times D$	F.x R.F.		
	S _{f2}			11.4			



Settlement Calculation As per IS 800	Mi	Minor Bridge Ch. 183/27-184/3						
BH No. (A1)								
Depth of foundation			=		6.0	m		
Length of footing (L)			=		8.0	m		
Width of footing (B)			=		2.0	m		
Initial effective stress at mid of layer	Po		=		14.25	t/m ²		
Concentrated load P			=		12.00	t/m²		
Incerase in pressure at mid of layer	ΔΡ		=		$P \times I_B$			
		1 B	=		0.21			
	ΔΡ		=		2.5	t/m ²		
Compression Index	Cc		=		0.14			
Thickness of clay layer	H		=		3	m		
Initial Void ratio	\mathbf{e}_{o}		=		0.75			
	Po + 4	Δp Po		=	1.176842105			
Settlement of clay layer		Sf		=	Cc	- н	log 10	$\frac{Po + \Delta}{Po}$
semental of early layer	•	-1			1+ eo		22.0	Po
		Si		=	0.016972368	m		
			=		17.0	mm		
Correction for Depth and Rigidity of Depth Factor Calculation	found	ation or	1 tota	al settle	ment			•
	D/I	L B)^ 0.5		=	0.47			
		,			0.67			
D = Depth of Foundation		,			0.67			
D = Depth of Foundation	I	L/B		=	4.00			
	Ī			=	4.00			
D = Depth of Foundation Depth Factor	ī	L/B		-	4.00			
		L/B Total		= lement	4.00 0.74 of Rigid founds			
		L/B Total		= lement	4.00		tion	_
Depth Factor		L/B Total		= lement	4.00 0.74 of Rigid founds		tion	_
Depth Factor Rigidity Factor =		L/B Total		= lement	4.00 0.74 of Rigid founds		tion	
Depth Factor Rigidity Factor = = 0.8		L/B Total		= lement	4.00 0.74 of Rigid founds	founda	tion	



CHAPTER - 5

"Minor Bridge No. 227A",

Location - Existing Km. - 184/19-21



5.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1x 2 x 2

5.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 7.00m below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
	0.00 to 4.50 4.50 to 7.50	Sandy Silt with Clay Sandy Silt with Clay	Loose Medium Dense
BH-1	7.50 to 12.00	Clayey Silt with Sand & Gravels	Medium Dense

5.3 CHEMICAL ANALYSIS OF SOIL:

BORE	HOLE	CHEMICAL PROPERTIES							
No.	Depth	pН	Carbonate	Chlorides	Sulphate	Nitrate	Salinity		
	(m)			%	º/o	%	%		
BH-1	3.00	8.20	NIL	0.0021	NIL	0.0012	0.011		
DI 1-1	6.00		NIL	0.0025	NIL	0.0011	0.015		

5.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	11.00
D11-1	6.00	13.00

5.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

	pН		Sulphate	Organic	Inorganic	Acidity	Alkalinity	Total	Conducti
Chemical		mg/lit	mg/lit	Matter	Matter	(ml)	(ml)	Disso.	vity
Properties				mg/lit	mg/lit			Solids	(µS/cm)
			<u> </u>					(ppm)	
Test	7.0	70	128	132	701	0.4	4.28	840	1252
Result	7.0	/0	120	152	- 701	0.4	4.20	040	1352
Requirement	Not	2000 for	400	200	3000	5 ml of	25 ml of	-	
asper E:456	less	CC and		1		0.02	0.02		`
/ Morth's	then	500 for				normal	normal		
	6.0	RCC				NaoH	H₂SO ₄		

5.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	08.00
BH-1	3.00	09.50
DU-1	4.50	10.50
	• 6.00	11.50

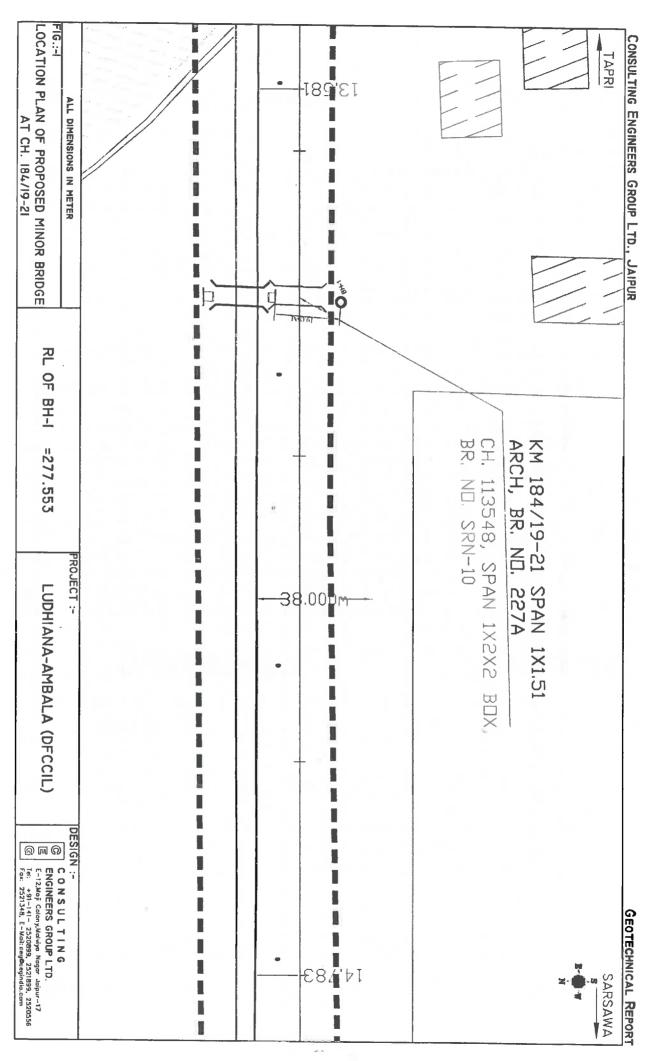
5.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

5.8 RECOMMENDATIONS

(i)	Type of foundation	Open foundation
(ii)	Depth of foundation below GL	Below 6.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



Geotechnical Report

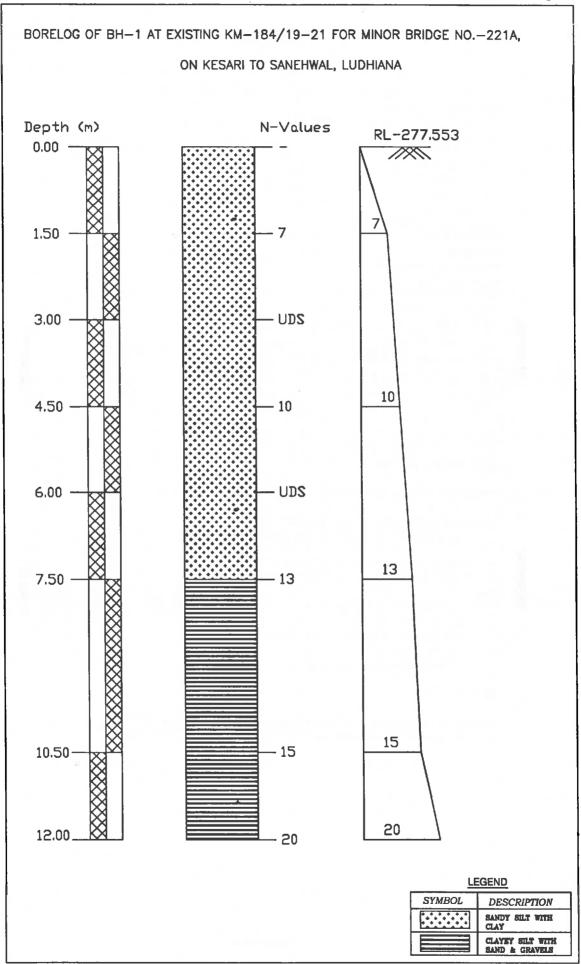
SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 227 A AT CHAINAGE 184/19-21		Me Termination Depth Surface Elevation	12.00mtr	Atterberg Limits % B.D. M.C. D.D. Specific Shear Strength	Gravity	arse L.L. P.L. P.I. gm/cc % gm/cc degree	00 32 24 8	00 30 23 7	00 33 24 9 1.76 12.95 1.57 2.65 0.1 20.0	00 33 25 8	00 36 26 10 1.86 17.33 1.59 2.64 0.12 18.0		00 39 28 11	00 40 27 13	CONSULTING Engineers Group Lid.
VOR BRIDGE		Depth of Water Table	07.00 ш.	rt retained	Gravel	Coarse Fine Coarse	0.68 4.25 0.00	0.40 11.32 0.00	0.35 3.65 0.00	0.30 0.00 0.00	1.14 2.35 0.00	0.92 7.16 0.00	1.15 6.63 0.00	1.50 10.38 0.00	
-1 FOR MIN		B.H. No.	-	Grain Size Distribution % wt retained	Sand	Fine Medium	10.52 0.85	8.45 1.00	13.62 1.35	31.82 1.36	26.66 2.51	11.95 2.34	9.61 2.34	12.37 2.66	
OLE AT BH		Location at	-	Grain	_	Sign of the control o	9.32 74.38	8.42 70.41	11.15 69.88	9.36 57.16	12.65 54.69	13.10 64.53	13.86 66.41	15.92 57.17	
ISTICS OF BORE H		Date of Testing	23.12.2009 to 23.12.2009	Soil	Description	(Soil Group)	Sandy Sift with Clay	Sandy Silt with Clay	Sandy Silt with Clay	Sandy Silt with Clay	Sandy Silt with Clay	Clayey Silt with sand and Gravels	Clayey Sit with sand and Gravels	Clayey Silt with sand and Gravels	
ACTER		-		Corrected		ž		10.08		10.70		11.70	11.70	14.80	
CHAR		Chainage 184/19-21	Bridge No. 227 A	Correction	Factor	ပ်	,	1.44		1.07		0.90	0.78	0.74	
IIOS		Chair	Brio	Observ-	pe pe	z		7	san	10	SQN	13	70	50	
	-		Project :	Depth	from	GL (m)	0.00	1.50	3.00	4.50	6.00	7.50	10.50	12.00	

0

-

0

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Calculation of SBC for shallow foundations as per IS: 6403 - 1981

INPUT DATA

Ch 184 19-21

BH-1

Туре о	f footing		
1	Continuous Strip		
2	Rectangular	Rectangular	2
3	Square		

Angle of internal friction (ϕ^{a})	18.00
Cohesion (c in 1/m2)	1.20
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (Vm³)	1.70
Density of foundation soil (1/m³)	1.86
Deoth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	2.00	8.00
2	3.00	2.00	8.00
3	4.50	2.00	8.00
4	6.00	2.00	8.00
•	0.00		

SHEAR FAILURE CRITERIA

Circular

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_s=c\;N_c\,s_c\,d_c\,i_c+q\;(N_q\text{--}1)\;s_q\,d_q\,i_q+(1/2)\;B\;\gamma\,N_y\,s_y\,d_y\,i_y\,W'$

The ultimate net bearing capacity in case of local shear failure is given by $q'_d = (2/3) \ c \ N'_c s_c \ d_c \ i_c + q \ (N'_{q} \cdot 1) \ s_q \ d_q \ i_q + (1/2) \ B \ \gamma \ N'_{\gamma} s_{\gamma} \ d_{\gamma} \ i_{\gamma} W'$

Where,

 $\begin{array}{l} d_c = 1 + 0.2 \; (\text{D/B})^* \text{SQRT}(\text{N}_{\phi}) & \bullet \\ d_q = d_\gamma = 1 \; \text{for} \; \phi < 10^\circ \\ d_q = d_\gamma = 1 + 0.1 \; (\text{D/B})^* \text{SQRT}(\text{N}_{\phi}) \; \text{for} \; \phi > 10^\circ \\ \text{N}_{\phi} = \tan^2(\pi/4 + \phi/2) \\ \phi' \; \text{for local shear failure} = \tan^{-1} \left(\; 0.67 \; tan\phi \; \right) \end{array}$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

12.28 9.55 3.14 1.87

Bearing capacity factors :

ø	18.00		φ,
N _c	13.29	•	N'c
N _q	5.42		N' _q
N,	4.29		N',

Shape factors:

S.no.	Width(m)	Length (m)	S _c	S_q	s,
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90
3	2.00	8.00	1.05	1.05	0.90
4	2.00	8.00	1.05	1.05	0.90

Depth factors:

S.no.	Depth(m)	Width(m)		dc	dq	d,
1	1.50	2.00		1.21	1.10	1.10
2	3.00	2.00	•	1.41	1.21	1.21
3	4.50	2.00		1.62	1.31	1.31
4	6.00	2.00		1.83	1.41	1.41

inclination factors:

$i_c = (1-\alpha/90)^2$	$i_a = (1-\alpha/90)^2$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z _w /B	W,
1	1.50	2.00	0.00	0.50
2	3.00	2.00	-0.75	0.50
3	4.50	2.00	-1.50	0.50
4	6.00	2.00	-2.25	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	2.00	8.00	13.85	6.61	8.42
2	3.00	2.00	8.00	15.67	7.48	9.53
3	4.50	2.00	8.00	17.49	8.35	10.64
4	6.00	2.00	8.00	19.31	9.22	11.74



Settlement Calculation As per	IS 8009 (I	Part 1)			Minor	Bridge Ch.	184/19-21
BH No. (A1)							
Depth of foundation		=		1.5	m		
Length of footing (L)		=		8.0	m		
Width of footing (B)		=		2.0	m		
Initial effective stress at mid of	lay Po	= 1		5.4	t/m ²		
Concentrated load P		=		8.00	t/m²		
Incerase in pressure at mid of la	ay€∆P •	=		$P \times I_B$			
•		I .		0.195			
	ΔΡ	=		1.6	t/m ²		
Compression Index	Cc	=		0.117			
Thickness of clay layer	Н	=		3	m		
Initial Void ratio	e_o	=		0.7			
	$\frac{\text{Po} + \Delta}{\text{Po}}$		=	1.2888889			
6	S	_	= 1	Cc 1+ eo	- н	log 10	$Po + \Delta P$
Settlement of clay layer	رد	f		1+ eo	••	810	Po
	S	f	=	0.0227563	m		
	S	f =	=				
Correction for Depth and Rigic		_		22.756255	mm		
Correction for Depth and Rigic		_		22.756255	mm		
Correction for Depth and Rigion Depth Factor Calculation	dity of fou	= indation		22.756255	mm		
Depth Factor Calculation		= indation		22.756255 settlement	mm		
Correction for Depth and Rigion Depth Factor Calculation D = Depth of Foundation	dity of fou D/(L	= undation B)^ ^{0.5}		22.756255 settlement 0.38	mm		
Depth Factor Calculation	dity of fou D/(L	= indation		22.756255 settlement	mm		
Depth Factor Calculation	dity of fou D/(L	= undation B)^ ^{0.5}		22.756255 settlement 0.38	mm		
Depth Factor Calculation D = Depth of Foundation	dity of fou D/(L	= undation B)^ ^{0.5}		22.756255 settlement 0.38 4.00	mm		
Depth Factor Calculation	dity of fou D/(L E /	= undation B)^0.5	on total	22.756255 settlement 0.38 4.00	mm :		
Depth Factor Calculation D = Depth of Foundation	dity of fou D/(L E /	= undation B)^0.5 /B	on total	22.756255 settlement 0.38 4.00 0.83 of Rigid for	mm		
Depth Factor Calculation D = Depth of Foundation	dity of fou D/(L E /	= undation B)^0.5 /B	on total	22.756255 settlement 0.38 4.00	mm	dation	
Depth Factor Calculation D = Depth of Foundation Depth Factor	dity of fou D/(L E /	= undation B)^0.5 /B	on total	22.756255 settlement 0.38 4.00 0.83 of Rigid for	mm	lation	
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = = 0.8	dity of fou D/(L E /	= undation B)^0.5 /B	on total	22.756255 settlement 0.38 4.00 0.83 of Rigid for	mm	dation	_
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = 0.8 Pore Pr. Correction = N.A.	dity of fou D/(L E /	= andation B)^0.5 /B	on total	22.756255 settlement 0.38 4.00 0.83 of Rigid for	nım indation xible found	lation	
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = = 0.8	D/(L D/(L E/ Total Set	= undation B)^0.5 /B	on total	22.756255 settlement 0.38 4.00 0.83 of Rigid for	mm	lation	_



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Settlement Calculation As per IS	3009 (1	Part 1)			Minor B	ridge Ch. 18	84/19-21
BH No. (A1)								
Depth of foundation			=		3.0	m		
Length of footing (L)			=		8.0	m		
Width of footing (B)			=		2.0	m		
Initial effective stress at mid of laye	Po Po		=		8.1	t/m ²		
Concentrated load P			=		9.50	t/m ²		
Incerase in pressure at mid of layer	ΔP		=		PxIB			
		I	B =		0.195			
	ΔΡ		=		1.9	t/m ²		
Compression Index	Cc		=		0.117	-,		
Thickness of clay layer	Н		=		3	m		
Initial Void ratio	e _o		=		0.7			
	Po+	Δp Po	-	=	1.2287037			
Settlement of clay layer		S _f		=	Cc	- н	lo-	Po + ΔP
Settlement of clay layer		J _f		-	1+ eo	- п	log 10	Po
		S_f		=	0.0184682	m		
		Sf	_	=				
Correction for Depth and Rigidity			= on or	= n total s	18.468209			
			= on or	= n total s	18.468209			•
	of fou	ndatio		= n total s	18.468209 settlement			
Depth Factor Calculation	of fou			= n total s =	18.468209			•
Correction for Depth and Rigidity Depth Factor Calculation D = Depth of Foundation	of fou	ndatio		= n total s =	18.468209 settlement			•
Depth Factor Calculation	of four	ndatio		total s	18.468209 settlement			
Depth Factor Calculation	of four	ndatio		= e total s	18.468209 settlement 0.75			
Depth Factor Calculation	of four	ndatio		= total s	18.468209 settlement 0.75			
Depth Factor Calculation D = Depth of Foundation	of four	ndatio		= total s	18.468209 settlement 0.75			
Depth Factor Calculation	of four D/(I	ndatio	.5	= :	18.468209 settlement 0.75 4.00 0.78	mm		
Depth Factor Calculation D = Depth of Foundation Depth Factor	of four D/(I	ndationLB)^0. ./B	.5 Settl	= = = ement	18.468209 settlement 0.75 4.00 0.78 of Rigid fou	mm undation	ation	
Depth Factor Calculation D = Depth of Foundation Depth Factor	of four D/(I	ndationLB)^0. ./B	.5 Settl	= = = ement	18.468209 settlement 0.75 4.00 0.78	mm undation	ation	
Depth Factor Calculation D = Depth of Foundation Depth Factor	of four D/(I	ndationLB)^0. ./B	.5 Settl	= = = ement	18.468209 settlement 0.75 4.00 0.78 of Rigid fou	mm undation	ation	
Depth Factor Calculation D = Depth of Foundation Depth Factor	of four D/(I	ndationLB)^0. ./B	.5 Settl	= = = ement	18.468209 settlement 0.75 4.00 0.78 of Rigid fou	mm undation	ation	
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = To = 0.8 Pore Pr. Correction = N.A.	of four D/(I	ndationLB)^0. ./B	.5 Settl	= = = ement	18.468209 settlement 0.75 4.00 0.78 of Rigid fou	mm undation	ation	
Depth Factor Calculation D = Depth of Foundation Depth Factor Rigidity Factor = To	of four D/(I	ndationLB)^0. ./B	.5 Settl	= = = ement	18.468209 settlement 0.75 4.00 0.78 of Rigid four	mm undation	ation	



	IS 8009 (I	Part 1)			Mino	Bridge Ch	. 184/19-21
BH No. (A1)	_						
Depth of foundation	•	=		4.5	m		
Length of footing (L)		=		8.0	m		
Width of footing (B)		=		2.0	m		
Initial effective stress at mid of	lay Po	=		10.8	t/m²		
Concentrated load P		=		10.50	t/m ²		
Incerase in pressure at mid of I	lay€∆P	=		PxIB			
-	•	$I_B =$		0.195			
	ΔΡ	=		2.0	t/m ²		
Compression Index	Cc	=		0.117	•		
Thickness of clay layer	Н	=		3	m		
Initial Void ratio	eo	=		0.7			
	Po + A		=	1.1895833			
Settlement of clay layer	S	_	=	Cc 1+ eo	- н	log 10	<u>Po + ΔP</u>
Settlement of Clay Tayer	51	i		1+ eo		10810	Po
	S		_	0.0155668	m		
	<i>5</i> ₁	i					
		523		15.566823			
Correction for Depth and Rigion Depth Factor Calculation	dity of fou	indation	on tota	u settiement			
Depth I detor Carcaration							
Separation Culturality	LB)^0	^{0.5} /D	=	0.89			
D = Depth of Foundation	LB)^0	^{0.5} /D	=	0.89			
	LB)^ ⁰	•	=	0.89 4.00			
D = Depth of Foundation	,	•	=	4.00			
	L/	В		4.00	- John		
D = Depth of Foundation	L/	B otal Sett	lement	4.00 0.74 of Rigid for		lation	_
D = Depth of Foundation	L/	B otal Sett	lement	4.00		lation	_
D = Depth of Foundation Depth Factor	L/	B otal Sett	lement	4.00 0.74 of Rigid for		lation	_
D = Depth of Foundation Depth Factor Rigidity Factor =	L/	B otal Sett	lement	4.00 0.74 of Rigid for		lation	_
D = Depth of Foundation Depth Factor Rigidity Factor = = 0.8	L/	B otal Sett	lement	4.00 0.74 of Rigid for centre of Flex		lation	_



CHAPTER - 4

"Minor Bridge No. 228",

Location - Existing Km. - 185/05-07



LOCATION OF STRUCTURE: 4.1

Proposed Minor Bridge of Span 1 x 2 x 2

BOREHOLE DESCRIPTIONS: 4.2

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 5.00m below EGL.

Subsurface BOREHOLE	profile at the site Depth	Type of Soil/Rock	Soil/Rock Characteristics
No. BH-1	(m) 0.00 to 4.50 4.50 to 6.00 6.00 to 12.00	Sandy Silt with Clay Silty Sand Sand	Loose Medium Dense Medium Dense

4.3

CHEMICAL ANALYSIS OF SOIL:	MICAL PRO	OPERTIES	3	
BOREHOLE	hlorides Si	ulphate	Nitrate	Salinity
No. Depth pH Carbonate Cl	%	%	%	%
(m)	0.0024	NIL	0.0012	0.009
3.00 7.90	0.0024	NIL	0.0013	0.010
BH-1 6.00 8.10 NIL	0.0019			

1	DIFFERENTIAL FREE SWELL I Bore Hole No. BH-1	Depth (m) 3.00 6.00	DFS Index in % 13.00 NIL

CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE 4.5

CHEM Chemical Properties	pH Value	ANALYSI Chlorides mg/lit	S OF EN Sulphate mg/lit	COUNT Organic Matter mg/lit	ERED W. Inorganic Matter mg/lit	ATER FI Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
			123	132	873	0.2	3.2	1010	1563
Test Result	6.7	69		200	3000	5 ml of	25 ml of	-	-
Requirement	Not	2000 for	400	200	3000	0.02	0.02		
asper 15:456	less	CC and			1	normal	normal	1	
/ Morth's	then			1		NaoH	H ₂ SO ₄	<u> </u>	
	6.0	RCC	1						

NET ALLOWABLE BEARING PRESSURE 4.6

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
	1.50	07.50
1	3.00	08.50
BH-1	4.50	15.00
	6.00	17.00

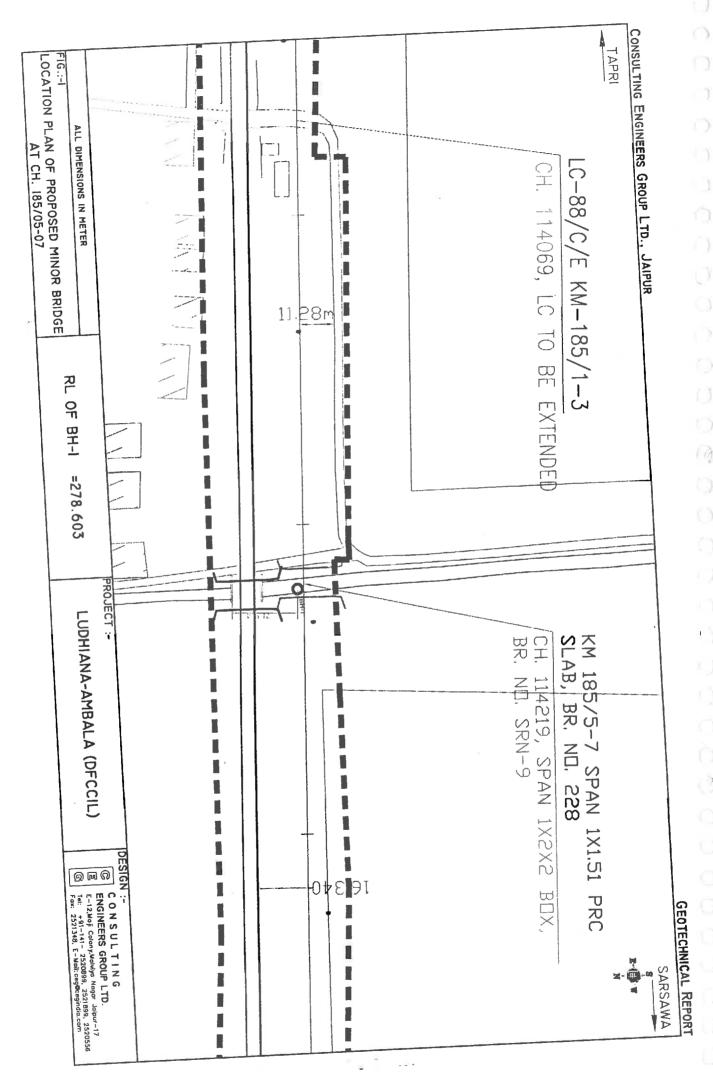
CONCLUSIONS 4.7

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

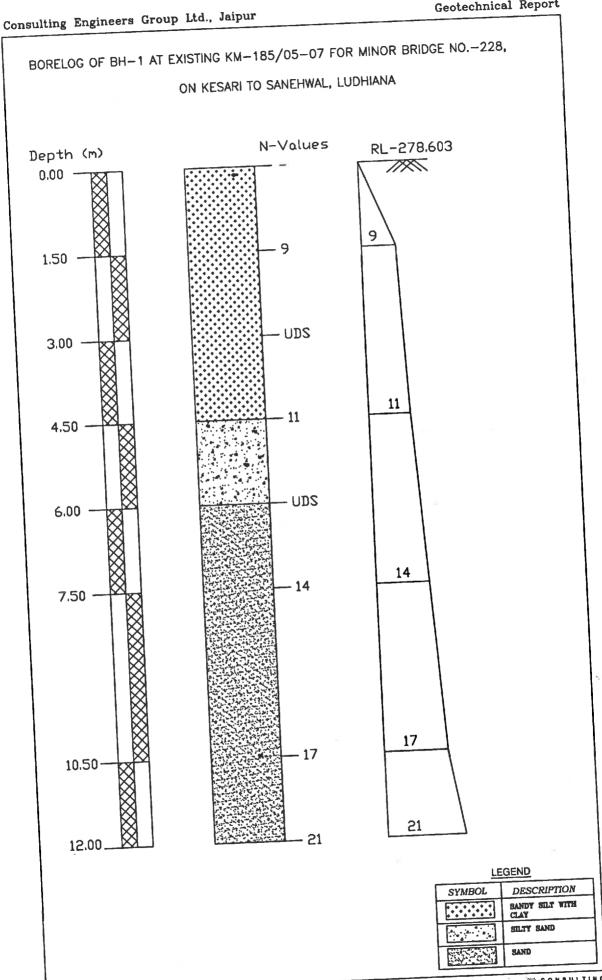
RECOMMENDATIONS

RECO	OMMENDATIONS	Open foundation
(i)	Type of foundation Depth of foundation below	
(ii)	GL	Delow Lee

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



A service of the serv	IOS	L CHA	RACTE	SOIL CHARACTERISTICS OF BORE	E HOLE	A	111	און שנ	BH-I FOR MINON DISC.			-	_					7	
r									1	1	-		Danth .	L		Surface	Surface Elevation	ç	
_				Corto of Toeting	Location at	næt	B.H. No.	ġ	Depth of	Depth of Water Table	용	Bulleria	BITTENBION DEPTH	1					
	Chair	Chainage 185/05-07		Aureau in AIRO			-		8	05.00 m.		12.0	12.00mtr	1				Change Strength	1
Project :	P	Bridge No. 228		23.12.2009 to 23.12.2009			die die	benishindion % art retained	n retained		-	Atterberg	Atterberg Limits %	8.D.	Ϋ́C	o.o.	Spacific	Shear Suer	
+	- Speed	Correction	Corrected	Soil			nein Azic L			Grava	\ \ _	-	-				Gravity	c ka/cm²	•
Deptu	-			Description	į	Ť		Sand	1	: H	+	-	P.L	am/cc	×	ам/ос		0	degree
	8	Lacio		Colored Barel	Ì	5	Fire	Medium	Coarse	eu L	Coarse	+	+	十					
GL (m)	2	ပ်	ź	(1000 000)				30.04	77	59.	0.00		21 10	_	•	,			,
900			,	Sandy Sitt with Clay	12.14	20.96	18.65	10.63			1	+	+	+		I			-
+				e Clark	9.65	52.10	21.16	8.87	7.12	1.10	•00.0	8	<u>2</u>	•	•			•	'
1.50	ø	44.	12.96	10 (MIR)						1			\$	1.72	12.94	1.52	2.65	0.11	20.0
+	99			Sandy Silt with Clay	11.68	50.64	19.62	10.47	6.34	12	0.00	8	8	-+		-			
3.00	800				1				8	98	0.00	27	N N N			•	٠		,
	Ξ	1.07	11.77	Silty Sand	3.95	10.11	7.4	6.1				+	+	+	+	1			L
		-	1		_		3	30 GE	0.35	00:00	0.00	ន		NP 1.86	19.14	1.58	2.67	0.0	28.0
9.00	SQN	•	,	Sand	0.00	2:38	9.18					\top	+	+	+	1-		-	
+		1	1	Sand	0.00	3.55	80.75	35.54	0.16	0.00	0.00	8	d d	ď	-	-		1	1
7.50	4	0.88	15.3		\downarrow	\downarrow	1		+		8	32	ž	ď.		,	<u>'</u>	•	
	2	0.78	13.26	Sand	0.00	2.47	56.67	40.00	0.70	9.10	3		-+	+	+	+	1	-	1
0.00	:	1	1			8	8	65.50	0.71	0.0	0.00	8	N N	- A		<u>'</u>	•	•	•
12.00	2	0.74	15.27	Sand	0.00	\dashv	\dashv	-	4		1		1	1	-			5.5 E)**	CONSULTING Engineers Group Lbs.
																		1	



Calculation of SBC for shallow foundations as per IS: 6403 - 1981

BH-1

Tune	of	footing
סעע י	u	<i>IUUIIII</i>

77			
1	Continuous Strip		
2	Rectangular	Rectangular	2
3	Square		
4	Circular		

Angle of internal friction (\$\phi^0\$)			20.00
Cohesion (c in t/m2)			1.10
Void ratio (e)	•		0.74
Direction of load with vertical (°)			0.00
Density of surcharge (t/m³)			1.70
Density of foundation soil (t/m3)			1.82
Depth of water table(m)			1.50
Factor of safety			3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	2.00	8.00
2	3.00	2.00	8.00
			•

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d = c \; N_e \, s_e \, d_e \, i_e + q \; (N_q \cdot 1) \; s_q \, d_q \, i_q + (1/2) \; B \; \gamma \, N_\gamma s_\gamma d_\gamma i_\gamma W^*$

The ultimate net bearing capacity in case of local shear failure is given by

$$q_{d}' = (2/3) c N_{c}' s_{c} d_{c} i_{c} + q (N_{q}'^{-1}) s_{q} d_{q} i_{q} + (1/2) B \gamma N_{\gamma}' s_{\gamma} d_{\gamma}' i_{\gamma} W'$$

Where,

 $d_c = 1 + 0.2 (D/B)^*SQRT(N_0)$

 $d_0 = d_v = 1 \text{ for } \phi < 10^\circ$

 $d_q = d_\gamma = 1 + 0.1 \ (D_r/B)^* SQRT(N_\phi) \ \text{ for } \phi > 10^{\circ}$

 $N_{\phi} = \tan^2(\pi/4 + \phi/2)$

φ' for local shear failure = tan-1 (0.67 tanφ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors:

ф	20.00
N _c	14.83
N _q	6.40
N,	5.39

φ'	13.70
N' _c	10.30
N' _q	3.56
N',	2.28

Shape factors:

S.no.	Width(m)	Length (m)	Sc	S_q	s,
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d,
1	1.50	2.00	1.21	1.11	1.11
2	3.00	2.00	1.43	1.21	1.21
_	0.00				

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1 - \alpha / 90)^2$	$i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z"/B	W'
1	1.50	2.00	0.00	0.50
2	3.00	2.00	-0.75	0.50
			•	

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	2.00	8.00	15.68	7.27	7.69
2	3.00	2.00	8.00	17.75	8.23	8.71
_	0.00					



Calculation of SBC for shallow foundations as per IS: 6403 - 1981

		Ch 185 5-7	BH-1	
Туре	of footing	•		
1	Continuous Strip			
2	Rectangular		Rectangular	2
3	Square			
4	Circular			
Angle	of internal friction (¢°)			29.00
Cohes	ion (c in t/m2)			0.00
Void ra	atio (e)			0.71

Concason (C in this)	0.00
Void ratio (e)	0.71
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m³)	1.86
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	4.50	2.00	8.00
2	6.00	2.00	8.00
		•	

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\,s_c\,d_c\,i_c+q\;(N_q\text{--}1)\;s_q\,d_q\,i_q+(1/2)\;B\;\gamma\,N_\gamma s_\gamma\,d_\gamma i_\gamma W^*$

The ultimate net bearing capacity in case of local shear failure is given by $q_d^\prime = (2/3) \ c \ N_c^\prime s_c d_c \, i_c + q \ (N_q^\prime - 1) \ s_q \, d_q \, i_q + (1/2) \ B \ \gamma N_\gamma^\prime s_\gamma^\prime d_\gamma^\prime i_\gamma^\prime W^\prime$

Where,

$$\begin{split} &d_{c}=1+0.2~(D/B)^{*}SQRT(N_{\phi})\\ &d_{q}=d_{y}=1~for~\phi<10^{\circ}\\ &d_{q}=d_{y}=1+0.1~(D/B)^{*}SQRT(N_{\phi})~for~\phi>10^{\circ}\\ &N_{\phi}=tan^{2}(\pi/4+\phi/2)\\ &\phi'~for~local~shear~failure=tan^{-1}~(~0.67~tan\phi~) \end{split}$$

<u>OUTPUT</u>

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

Bearing capacity factors :

φ	29.00
N _c	28.26
N _q	16.85
N _y	20.10

φ'	20.37
N' _c	15.27
N' _q	6.72
N' _y	5.80

Shape factors:

S.no.	Width(m)	Length (m)		Sc	S_q	S,
1	2.00	8.00	•	1.05	1.05	0.90
2	2.00	8.00		1.05	1.05	0.90

Depth factors:

S.no.	Depth(m)	Width(m)	dc	dq	dγ
1	4.50	2.00	1.76	1.38	1.38
2	6.00	2.00	2.02	1.51	1.51

Inclination factors:

$i_c = (1-\alpha/90)^2$	$i_a = (1-\alpha/90)^2$	$i_{y} = (1 - \alpha / \phi)^{2}$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z"/B	W'
1	4.50	2.00	-1.50	0.50
2	6.00	2.00	-2.25	0.50

Sale Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	4.50	2.00	8.00	33.82	11.64	16.08
2	6.00	2.00	8.00	36.93	12.71	17.56

Settlement Calculation As per IS 8009 (Pa	rt 1)			Mino	r Bridge Ch.	185/0 5-07
BH No. (A1)						
Depth of foundation		=	1.5	m		
Length of footing (L)		200	8.0	m		
Width of footing (B)		=	2.0	m		
Initial effective stress at mid of layer	Po	=	5.4	t/m ²		
Concentrated load P		=	7.50	t/m ²		
Incerase in pressure at mid of layer	ΔP	=	PxIn	,		
		I B =	0.195			
	ΔP	=	1.5	t/m ²		
Compression Index	Cc	-	0.14	·		
Thickness of clay layer	H	=	3	m		
Initial Void ratio	eo	=	0.74			
	$Po + \Delta$	<u>р</u> _	1.2708333			
	Po		1.2708333			
Settlement of clay layer	Sr		Cc	- н	laa	Po + ΔF
, ,	75		1+ eo	**	log 10	Po
	•					
	Sf	=	0.0251248	m		
		_	25.124834	m.m.		
Correction for Depth and Rigidity of found	ation on tota	l settlement	23.124034	man		
Depth Factor Calculation						
	D/(LB	\A0.5	0.38			
D-D 11 4B 141	D/ (LD	, -	0.00			
D = Depth of Foundation						
	L/E	3 =	4.00			
Depth Factor		-	0.82			
	Т	otal Settlen	nent of Rigid fo	undation		
731 1 111 F3 4	Total Set	tlement at	the centre of Flo	xible four	ndation	-
Rigidity Factor =						
	3					
= 0.0	-					
= 0.0	B .A.	=	S. x D	F.x R.F.		



(3)

Settlement Calculation As per IS 8009 (Part 1))				Mino	r Bridge Ch. 1	185/05-07
BH No. (A1)							
Depth of foundation		=		3.0	m		
Length of footing (L)		=		8.0	m		
Width of footing (B)		=		2.0	m		
Initial effective stress at mid of layer	Po	=		6.75	t/m²		
Concentrated load P		=		8.50	t/m²		
Incerase in pressure at mid of layer	ΔΡ	=		PxIB			
		1 _B =		0.195			
	ΔΡ	=		1.7	t/m²		
Compression Index	Cc	=		0.14			
Thickness of clay layer	H	=		1.5	m		
Initial Void ratio	e _o	=		0.74			
	Po+	Δp	=	1.2455556			
	_	_		Cc	••	1	Po + ΔP
Settlement of clay layer	:	Sr.	=	1+ eo	- н	log 10	Po
	;	Sí	=	0.0115093	m		
		_		11.50934	m. m.		
Correction for Depth and Rigidity of foundation Depth Factor Calculation	on on to	tal settler	nent	11.50954	шш		
	D/(L	.B)^ ^{0.5}	=	0.75			
D = Depth of Foundation							
	L	/B	=	4.00			
Depth Factor			=	0.77			
		Total Se	ttlemer	nt of Rigid fo	oundation	ı	
Rigidity Factor =	Total S			e centre of Fl			_
= 0.8							
Pore Pr. Correction= 0.85							
Total Settlement	_	=		•	.F.x R.F.		
		S ₁₂ =		6.0	mm		

Footing Depth (m)	3.00
SBC (t/m2)	1.70
Average N value	12
Settlement for 10 t/m2 (mm)	29.00
Total Settlement (mm)	4.93
Depth Correction	0.77
Rigidity Factor	0.8
Corrected Settlement (mm)	3.0
Total Settlement (mm)=	9.1

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Set	tlement Calculation As per IS 8009 (Pa	rt 1)
Location	Minor Bridge	
Chainage	185/05-07	
Bore Hole No.	1	

Footing Depth (m)	4.50
SBC (t/m2)	15.00
A	•
Average N value	13
Settlement for 10 t/m2 (mm)	27.00
Total Settlement (mm)	40.50
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	23.7

0

0

Footing Depth (m)	6.00
	•
SBC (t/m2)	17.00
Average N value	14
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	37.40
Depth Correction	0.7
Rigidity Factor	0.8
Corrected Settlement (mm)	20.9

CHAPTER - 3

"Minor Bridge No. 231",

- Location - Existing Km. - 186/17-19



3.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span 1 x 6.10

3.2 BOREHOLE DESCRIPTIONS:

- (a) Location of Structure, Boreholes with RL shown in FIGURE-1.
- (b) Subsurface Characteristic of Soil/Rock shown in ANNEXURE-I.
- (c) Borelogs and sub soil profile shown in ANNEXURE-II.
- (d) Calculations of Safe Bearing Capacities in ANNEXURE-III.
- (e) Calculations of Probable Settlement in ANNEXURE-IV.
- (f) Depth of water Table 6.00m below EGL.

Subsurface profile at the site

Subsurface	proffie at the site		
BOREHOLE	Depth	Type of Soil/Rock	Soil/Rock
No.	(m) -	•	Characteristics
	0.00 to 12.00	Silty Sand	Loose
BH-1	0.00 to 12.00	Dirty Daniel	

3.3 CHEMICAL ANALYSIS OF SOIL:

BORE	HOLE	CHEMICAL PROPERTIES						
No.			Carbonate	Chlorides	Sulphate	Nitrate	Salinity	
140.	(m)			%	0/0	%	%	
	3.00	8.40	NIL	0.0016	NIL	0.0013	0.011	
BH-1	6.00	8.30	NIL	0.0014	NIL	0.0011	0.009	

3.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
	3.00	NIL
BH-1	6.00	NIL

3.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conducti vity (µS/cm)
Test Result	6.9	65	135	126	682	0.3	4.80	816	1330
Requirement as per 15: 456 / Morth's		2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H ₂ SO ₄	-	-

3.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	3.00
	3.00	6.00

Bridge No. 231
50
.00
0

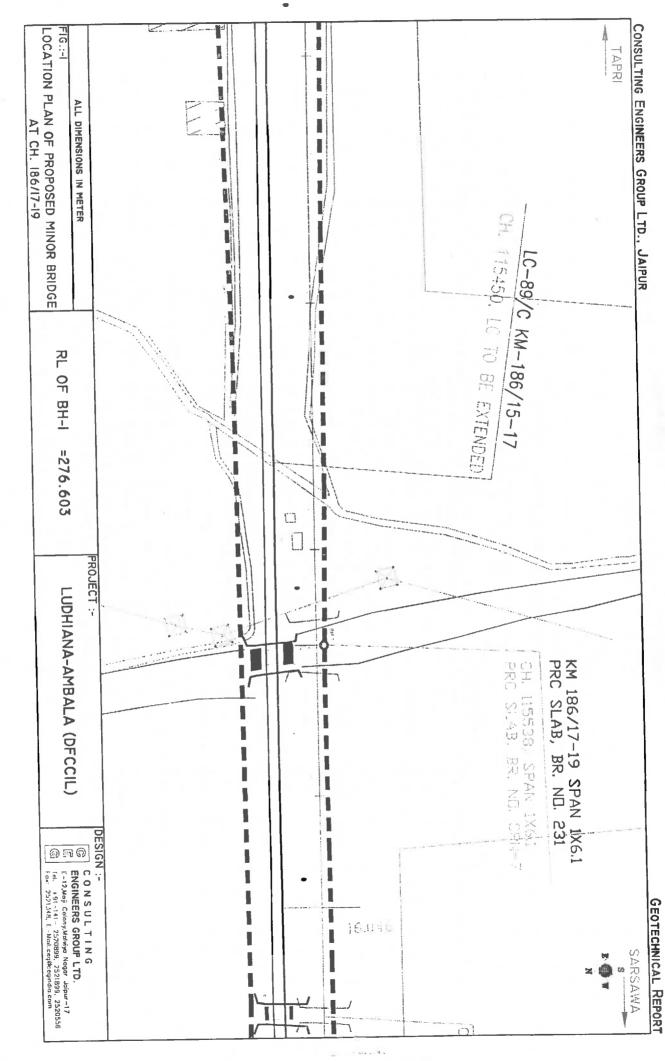
3.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

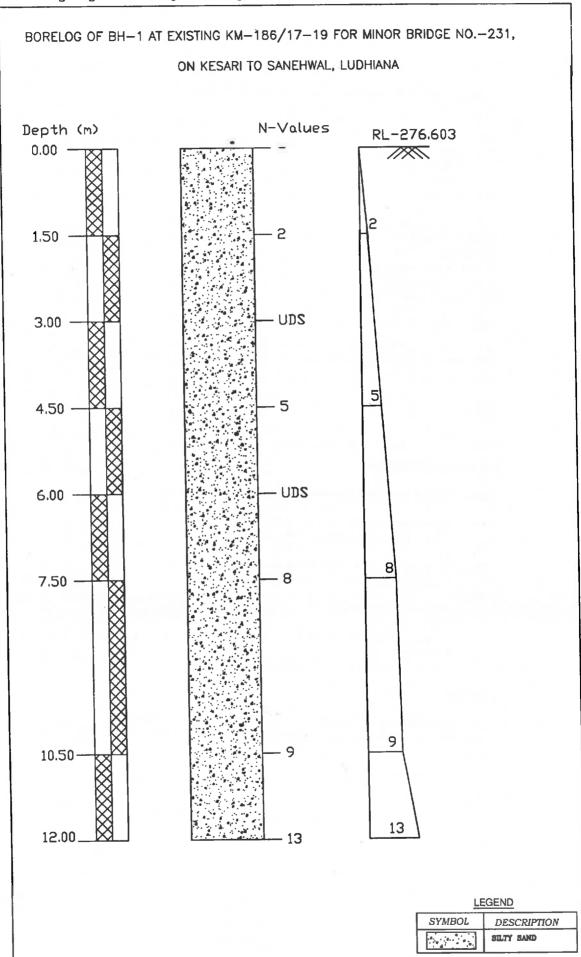
3.8 RECOMMENDATIONS

5	KEC	JMMENDATIONS	1 ((1 1 1 1			
ſ	(3)	Type of foundation	Open and raft foundation			
-	(1)		Below 6.00 m from EGL			
- 1		Depth of foundation below	Delow 0.00 III IIom 202			
	(ii)	. CI				
- 1	, ,	OL .				

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



			ngth	۰	degree		• .	29.0	•	28.0	,	,		C O N S U L T N G Engineers Group Ltd.
	5		Shear Strength	c kn/cm²		,	,	0.00		00.00				Engine
7-19	Surface Elevation		Specific	Gravity				2.65		2.62	,	,		
86/1	Surfac		D.D.	Ŭ	дш/сс		,	1.56		1.49				
GE			M.C.		%			8.26		16.15	1	,		
AINA			B.D.		gm/cc			1.69	,	1.73			,	
r CH	epth B		% SI		F.	Š	₽.	ē.	g.	ď.	Ž	ğ	Ā	
31 A7	Termination Depth	12.00mtr	Atterberg Limits %		P.L	불	Ę	불	F E	N.	불	jį į	Ę	
70.2	Теш		Attert		I.	27	30	26	29	27	30	88	8	
GE	Table			Gravel	Coarse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
BRII	Depth of Water Table	06.00 m.	 -	١	Fine	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	
NOR	Depth o	0	d retained		Coarse	1.52	8.1	0.68	0.00	1.68	1.24	0.39	0.00	
OR MI	9		Grain Size Distribution % wt retained	Sand	F		22.97	6.24	4.25	10.68	26.13	50.86	11.28	
H-1 F(B.H. No.	-	Size Distr		E G	+	66.44	73.26	83.29	64.18	61.16	37.26	70.87	
ATB	n at		Grair		Sir	9.02	5.44	16.26	8.25	19.10	6.61	7.45	13.93	
HOLE	Location at	-			Clay	3.14	4.12	3.56	4.21	4.36	4.86	3.88	3.92	
SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 231 AT CHAINAGE 186/17-19	Date of Testing	21.12.2009 to 21.12.2009	ico	Description	in the second	Silly Sand	Siliy Sand	Silty Sand	Silty Sand	Sity Sand	Silty Sand	Silty Sand	Silty Sand	
RACTE		 D		Colecied		ž ,	2.92		5.45		7,36	7.29	98.88	
L CHA		Chainage 185/17-19 Bridge No. 231		Correction	ractor	ပ် ၊	1.46		1.09		0.92	0.81	92.0	
SOI	3	Chain		>	8	z ,	2	Sau	'n	san	60	o	13	
		Project :		Depth	trom	GL (m)	1.50	3.00	4.50	6.00	7.50	10.50	12.00	



Calculation of SBC for shallow foundations as per IS: 6403 - 1981

	Ch	186	17-19
	011		

BH-1

		Oll 100 II IO			
Туре	of footing		F		
1	Continuous Strip				
2	Rectangular		Rectangular	2	
3	Square				
4	Circular				
A 1 -	of internal friction (o 0)			28.00	
_	of internal friction (o°)	•		0.00	
	sion (c in t/m2)			0.75	
	atio (e)			0.00	
	ion of load with vertical (°)			1.69	
	ty of surcharge (t/m3)			1.69	
Densi	ty of foundation soil (t/m³)				
	of water table(m)			1.50	
Coolo	r of coloby			3.00	

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00

SHEAR FAILURE CRITERIA

Factor of safety

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

 $q_d = c N_c s_c d_c i_c + q (N_q-1) s_q d_q i_q + (1/2) B \gamma N_\gamma s_\gamma d_\gamma i_\gamma W'$

The ultimate net bearing capacity in case of local shear failure is given by

 $q_{d}^{\prime} = (2/3) \; c \; N_{c}^{\prime} \, s_{c} \, d_{c} \, i_{c} + q \; (N_{q}^{\prime} - 1) \; s_{q} \, d_{q} \, i_{q} + (1/2) \; B \; \gamma \; N_{\gamma}^{\prime} \, s_{\gamma}^{} d_{\gamma}^{} i_{\gamma}^{} W^{\prime}$

Where,

 $d_c = 1 + 0.2 (D_l/B)*SQRT(N_{\phi})$

 $d_q = d_{\gamma} = 1$ for $\phi < 10^{\circ}$

 $d_q = d_\gamma = 1 + 0.1 (D_l/B)^*SQRT(N_\phi)$ for $\phi > 10^\circ$

 $N_e = \tan^2(\pi/4 + \phi/2)$

 ϕ for local shear failure = tan^{-1} (0.67 $tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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Bearing capacity factors :

ф	28.00
N _c	26.37
N _a	15.30
N _y	17.79

 φ'	19.61
N'c	14.53
N' _q	6.21
N' _y	5.18

Shape factors:

Width(m)	Length (m)		Sc	Sq	S,
3.00	8.00		1.08	1.08	0.85
3.00	8.00		1.08	1.08	0.85
	3.00	3.00 8.00	3.00 8.00	3.00 8.00 1.08	3.00 8.00 1.08 1.08

Depth factors:

S.no.	Depth(m)	Width(m)	dc	d _q	d,
1	1.50	3.00	1.17	1.08	1.08
2	3.00	3.00	1.33	1.17	1.17

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_{\alpha} = (1-\alpha/90)^{2}$	 $i_y = (1 - \alpha / \phi)^2$
1.00	1.00	1.00

Water table factor:

S.no.	Depth(m)	Width(m)	Z"/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	21.00	7.14	7.14
2	3.00	3.00	8.00	37. 76	13.20	13.20



BH-1

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

Ch 186 17-19

INP	UT	DA'	ſΑ
			_

Type of	looting		
1	Continuous Strip		
2	Rectangular	Rectangular	2
3	Square		
4	Circular -		

Angle of internal friction (o o)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.75
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m³)	1.73
Depth of water table(m)	1.50
Factor of safety	3.00

Depth (m)	Width (m)	Length (m)
4.50	3.00	8.00
6.00	3.00	8.00
	•	
	4.50	4.50 3.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by $q_d=c\;N_c\;s_c\;d_c\;i_c\;+\;q\;(N_q^-1)\;s_q\;d_q\;i_q\;+\;(1/2)\;B\;\gamma\;N_\gamma s_\gamma d_\gamma i_\gamma W'$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3) c N'_c s_c d_c i_c + q (N'_q-1) s_q d_q i_q + (1/2) B \gamma N'_{\gamma} s_{\gamma} d_{\gamma} i_{\gamma} W'$$

Where,

 $d_c = 1 + 0.2 (D_t/B)*SQRT(N_\phi)$

 $d_q = d_\gamma = 1$ for $\phi < 10^{\alpha}$

 $d_q = d_r = 1 + 0.1 (D_l/B) SQRT(N_\phi)$ for $\phi > 10^\circ$

 $N_{\phi} = \tan^2(\pi/4 + o/2)$

φ' for local shear failure = tan⁻¹ (0.67 tanφ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.



Bearing capacity factors:

à	28.00
N _c	26.37
N _a	15.30
N.	17.79

φ'	19.61
N' _c	14.53
N' _q	6.21
N'.	5.18
1914	

Shape factors:

		All from	S.	S,	S,
S.no. 1 2	3.00 3.00	8.00 8.00	1.08 1.08	1.08 1.08	0.85 0.85

Depth factors:

				d	d.
S.no. 1 2	Depth(m) 4.50 6.00	3.00 3.00	1.50 1.67	1.25 1.33	1.25 1.33

Inclination factors:

	$i_a = (1-\alpha / 90)^2$	i, = (1- a	ι/φ) ²
$i_c = (1-\alpha/90)^2$		1.00	0
1.00	1.00		

Water table factor:

			Z _w /B	M,
S.no.	Depth(m)	Width(m)		0.50
1	4.50	3.00	-1.00	0.50
2	6.00	3.00	-1.50	5,00
			•	

Safe Bearing Capacity

	Depth(m)	Width(m)	Length (m)	SBC in (1/m²)		Antoni
.no.	Dobardon			General shear	Local shear	Actual
		2.00	8.00	40.84	14.27	14.27
1	4.50	3.00		43.56	15.22	15.22
2	6.00	3.00	8.00	43.30	10.20	



Settle	ement Calculation As per IS 8009 (Part 1)
	Minor Bridge 186/17-19 1

Footing Depth (m)	1.50
Footing Deptit (iii)	
SBC (t/m2)	3.00
Average N value	5
Settlement for 10 t/m2 (mm)	160.00
Total Settlement (mm)	48.00
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	34.9

Footing Depth (m)	3.00
Tooming I	
SBC (t/m2)	6.00
Average N value	6
Settlement for 10 t/m2 (mm)	100.00
Dettication	
Total Settlement (mm)	60.00
Depth Correction	0.82
Rigidity Factor	0.8
Corrected Settlement (mm)	39.4

Footing Depth (m)	4.50
Footing Depth (24)	
SBC (t/m2)	9,50
Average N value	7
Settlement for 10 t/m2 (mm)	68.00
	\
Total Settlement (mm)	64.60
Depth Correction	0.75
Rigidity Factor	0.8
	20.0
Corrected Settlement (mm)	38.8

Footing Depth (m)	6.00
SBC (t/m²)	10.00
SBC (VIIIZ)	
Average N value	7
Settlement for 10 t/m2 (mm)	68.00
Total Settlement (mm)	68.00
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	39.7

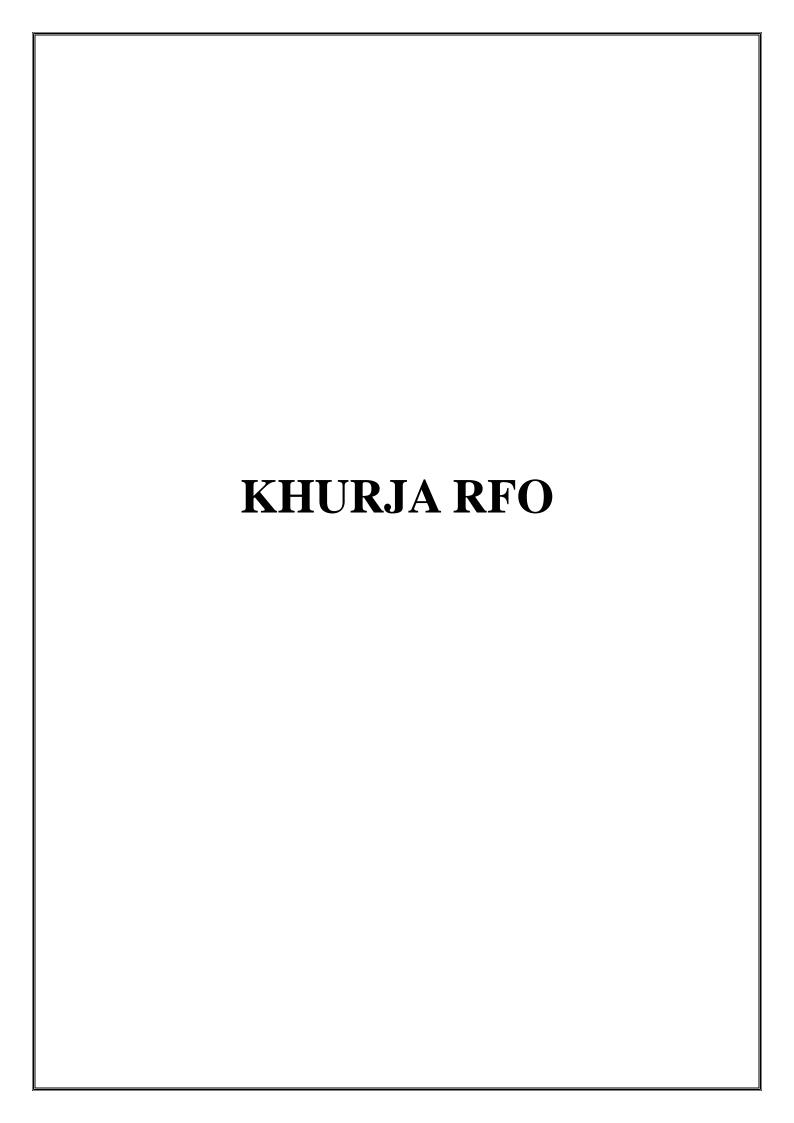


	Table 2.1: Laboratory Test Results on the Soil Samples Collected from CH (-)1600 Location																										
pu						C	lay									Sie	eve A	\nal _\	ysis			axial est	Be She		(kPa)		
R.L. of Sample below Existing Groulevel(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m ³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ф (Deg.)	c (kN/m²)	φ (Deg.)	Unconfined Compression Tests, Cu	Consolidation Tests, Cc	IS-Classification
			Silty Clayay Fina																			-					
E.G.L-7.50	23	SS	Silty Clayey Fine Sand	9	-	-	-	-	2.67	-	19	-	-	M.Dense	0	0	0	83	12	5	-	-	8.0	30.3	-	-	SM
7.50-12.00	37	SS	Silty Fine Sand	7	_	-	_	_	2.67	_	15	_	-	Dense	0	0	0	79	14	7	_	_	_	_	_	_	SM
7.00 12.00			zacj z me zana	,					2.07		10			201100	Ť	Ť	ľ										21.1

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Ch: (-) 1600										
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(pp	Sulphates (p						
BH-01	7.50	7.83	128.32	102.43						

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 CH: 1600 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 7.50m depth below)

Type of Strata Silty Clayey Fine Sand

Colour Brownish
Thickness of Layer 7.50m
SPT of the layer 24

Relative Density Medium Dense

Angle of Shearing Resistance 33.90°

* Layer-2 (from 7.50m to 12.00m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

SPT of the layer

Relative Density

Angle of Shearing Resistance

Silty Fine Sand

Brownish

4.50m

SPT of the layer

38

Dense

37.925°

The ground water table was encountered at a depth of 7.80m within the explored depth of investigation in the fourth week of February 2009.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are coarse-grained type and can be considered as bearing strata for proposed impending loads form the superstructure.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as coarse-grained soil strata can be considered as bearing strata.

The foundation system shall be located at a depth of 1.50m below the natural ground level (N.G.L). The safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure over the bearing strata.

The safe bearing capacity of raft located at a depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	

	(m)		
1	1.50	17	45

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths are coarse-grained type and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The foundation system shall be located at a depth of 2.00m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure over the bearing strata.
- 4. The safe bearing capacity of raft located at a depth of 2.00m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

 $\label{eq:Type of Footing: Isolated Column}$ Depth of foundation below the E.G.L: 1.50

Depth of foundation below the E.G.L: 1.50 m
Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 1.50 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Clayey Sand

Least SPT-value of the Bearing Strata: 18

Type of Shear Failure: General

Angle of Shearing Resistance, φ: 32.40 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 16.00 kN/m³

Effective Overburden pressure at foundation level (q) 9.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 25.55$

 $N_{\nu} = 34.70$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_{u} = 437.77 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 175.11 kPa

Limited to an allowable bearing pressure per running meter width: 170.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 170kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 170kPa and SPT of 18 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings and 70mm for rafts as per I.S:1904.

Project: Proposed Dedicated Freight Corridor at Khurja-Talheri at F1 on Eastern Freight Corridor in line with

Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At CH: (-)1600

Started On: 21/02/2009; Ended On: 21/02/2009 G.W.T: 7.80m

		Ī		72/2007, Ended On . 21/			etail		rapl		Repres	enta	atio	n o	fSP	>	
									##		2(3(4)					Suc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value							Relative Density/Consistency	Type of Sample
					1.50	8	8	11	19	٩						M.Dense	SS
				Brownish	3.00	UDS	Samp	ler Ins	talled							M.Dense	UDS
				Medium Dense Silty Fine Sand	4.50	9	11	13	24							M.Dense	SS
					6.00	10	14	14	28							M.Dense	SS
_	50 V.T	¥	Н		7.50	12	15	17	32							Dense	SS
				Brownish	9.00	12	15	50	35							Dense	SS
				Medium Dense Silty Fine Sand	10.50	10	19	25	44							Dense	SS
12	.00				12.00	11	20	27	47							Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at CH: (-)1600 Location**

	Table 2.1: Laboratory Test Results on the Soil Samples Collected from CH-(-)2356 Location																										
sting Ground			Visual &		Clay	lay							ency		Sie	eve A	naly	ysis			axial est	Bo	ox Shear	n Tests, Cu (kPa)			
R.L of Sample below Existing level(m)	SPT of Sample	Type of Sample	Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, $I_{\rm C}$	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	ф (Deg.)	Unconfined Compression	Consolidation Tests, Cc	IS-Classification
E.G.L-3.50	8	SS	Silty Clayey Fine Sand	12	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	83	11	6	-	-	6.8	30.0	-	-	SM
3.50-12.00	22	SS	Silty Fine Sand	7	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at CH-(-)2356													
Location of Bore Hole	Depth of Sample below E.G.L. (m)	Hd	Chlorides(ppm)	Sulphates (ppm)									
BH-01	9.00	7.82	121.24	89.31									

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

- * For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.
- * For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Ch-2356 Location

(As presented in the site plan)

* Layer-1 (from E.G.L to 3.50m depth below)

Type of Strata

Colour

Brownish

Thickness of Layer

3.50m

SPT of the layer 08
Relative Density Loose
Angle of Shearing Resistance 29.60°

* Layer-2 (from 3.50m to 12.00m depth below)

Type of Strata Silty Fine Sand Colour Brownish
Thickness of Layer 8.50m
SPT of the layer 22

Relative Density Medium Dense

Angle of Shearing Resistance 33.60°

The ground water table was encountered at a depth of 8.20m within the explored depth of investigation in the fourth week of February 2009.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are coarse-grained type and can be considered as bearing strata for proposed impending loads form the superstructure.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as coarse-grained soil strata can be considered as bearing strata.

The foundation system shall be located at a depth of 2.00m below the natural ground level (N.G.L). The safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure over the bearing strata.

The safe bearing capacity of raft located at a depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of	Safe Bearing	Elastic Settlements
	Foundation System	Capacity	(mm)
	below N.G.L	(t/m^2)	

	(m)		
1	2.00	11	48

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

- 1. The sub-soil stratifications encountered at shallow depths are coarse-grained type and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
- 2. The foundation system shall be located at a depth of 2.00m below the natural ground level (N.G.L).
- 3. The safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure over the bearing strata.
- 4. The safe bearing capacity of raft located at a depth of 2.00m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.
- 5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
- 6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
- 7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
- 8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data:

Type of Footing: Isolated Column

Depth of foundation below the E.G.L: 2.00

Observed Maximum thickness of Filled up Soil: 0.00 m

Effective Depth of Foundation below E.G.L: 2.00 m

Minimum Width of Foundation (B): 1.00 m

1 Soil Data:

Type of Bearing Strata: Silty Clayey Sand

Least SPT-value of the Bearing Strata: 8

Type of Shear Failure: General

Angle of Shearing Resistance, φ: 29.60 Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk}) 15.00 kN/m³

Effective Overburden pressure at foundation level (q) 10.00 kPa

Water Table Correction Factor (w') 0.50

Bearing Capacity Factors:

 $N_c = N/A$

 $N_q = 17.78$

 $N_{\gamma} = 21.48$

Shape Factors:

 $S_c = N/A$

 $S_q = 1.30$

 $S_{\gamma} = 1.00$

Depth Factors:

 $D_c = N/A$

 $D_{q} = 1.00$

 $D_{\gamma} = 1.00$

Inclination Factor:

 $I_c = N/A$

 $I_{q} = 1.00$

 $I_{v} = 1.00$

1 Ultimate Bearing Capacity (Qu):

 $Qu = Cu*Nc*Sc*D_{C}*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

 $Q_u = 311.69 \text{ kPa}$

2 Safe Bearing Capacity (Qsafe):

Factor of Safety (F.S.): 2.50

Qsafe: 124.68 kPa

Limited to an allowable bearing pressure per running meter width: 110.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 110kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 110kPa and SPT of 08 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings and 70mm for rafts as per I.S:1904.

Project: Proposed Dedicated Freight Corridor at Khurja-Talheri at F1 on Eastern Freight Corridor in line with

Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At CH-(-)2356

Started On: 22/02/2009; Ended On: 22/02/2009 G.W.T: 8.20m

~ `	urte	u O	11 . 22/(02/2009; Ended On: 22/	_				8.20									
					SP'	Γ - D	etail	S	rapl			•					<u></u>	
									##	10	213(4(5)6(7(8)90						enc	
Depth of Top of	Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value								Relative Density/Consistency	Type of Sample
				Brownish Loose Silty Clayey Fine Sand	1.50	3	3	5	8	9							Loose	SS
3	.50				3.00	UDS	Samp	ler Ins	talled	\setminus							Loose	UDS
				Brownish Medium Dense Silty Fine Sand	4.50	7	7	9	16	d							M.Dense	SS
					6.00	7	9	10	19		d						M.Dense	SS
	***				7.50	8	10	12	22								M.Dense	SS
G.	W.T	★ .			9.00	10	10	14	24								M.Dense	SS
					10.50	8	12	15	27		d	\					M.Dense	SS
13	2.00	<u> :</u>			12.00	11	14	17	31			J					Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level **Fig. 2.1 Soil Profile at CH-(-)2356 Location**